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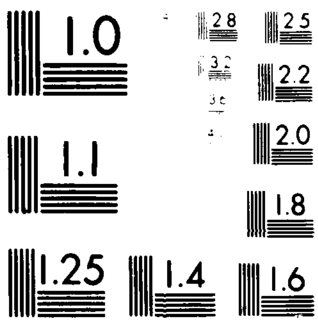

MICROCOPY RESOLUTION TEST CHART

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Aperture Integration

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report provides the necessary information to run a Fortran IV computer code by which the near field or the far field patterns of a typical Navy reflector antenna can be calculated. This code was developed as part of a larger effort to develop computer models for simulating antennas at UHF and above frequencies in a complex ship environment.

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> The theoretical approach for computing the fields of the general reflector is based on a combination of the Geometrical Theory of Diffraction (GTD) and Aperture Integration (AI) techniques. Various examples are presented to illustrate the versatility of the code as well as its operation.

CONTENTS

I. INTRODUCTION

This user's manual describes the operation of the Numerical Electromagnetics Code-Reflector Antenna Code. The code manual [1] describes the theory used in the code and documents a detailed explanation of the code.

The Reflector Code was designed to compute either near field curves or far field patterns of typical Navy reflector antennas. One important feature of the code is the capability for a general reflector rim shape. Another important feature is the capability to input a practically arbitrary volumetric feed pattern.

Since many Navy reflector antennas have parabolic surfaces, only the class of parabolic surfaces was implemented in the computer code. The geometry of the reflector rim is treated as piece-wise linear. The code for the reflector geometry is flexible enough to include offset fed reflectors and general reflector rim shapes such as elliptical and rectangular with chopped corners.

The theoretical approach for computing the fields of the general reflector is based on a combination of the Geometrical Theory of Diffraction (GTD) and Aperture Integration (AI) techniques. Typically AI is used to compute the main beam and near sidelobes; GTD is used to compute the wide-angle sidelobes and the backlobes. To implement the computer algorithms based on these theories, efficient ways were developed to handle calculations involving the feed pattern, the aperture field and the far field pattern computations.

Sampled data from each measured feed pattern cut is input and stored in the code. Linear interpolation is then used to obtain a piecewise linear representation of the input pattern cut. The feed patterns in planes other than those corresponding to the input pattern cuts also are calculated by linear interpolation. This method provides a computationally efficient way of calculating the aperture field without requiring large amounts of computer storage for the measured feed pattern. Only relatively few data points need to be stored for essentially complete feed pattern information. Furthermore, the piecewise linear method has the advantages of flexibility and simplicity for general feed patterns. No cut-and-try procedures are needed; the sample feed values can be obtained directly from measured feed pattern data.

The aperture fields are calculated and stored on the principal grid for use in the aperture integration. The principal grid values are used for all output pattern cuts. The aperture fields are calculated at points off the principal grid by using linear interpolation from the principal grid. This is more efficient than calculating the aperture fields from the feed pattern for each rotated grid that is used for off-principal plane cuts.

The aperture integration uses an approach of overlapping subapertures which allows a piecewise linear representation for the aperture distribution. Thus variations in the aperture fields can be represented with relatively few subapertures. Furthermore, the subapertures can be electrically large; thus minimizing the computer storage and also the amount of numerical integration required. For far field computations, a rotating grid method is employed in that the y-integrations are carried out for each column of the aperture and each one-dimensional integration result is stored. The stored values for the y-integration are then used for each pattern angle in the plane perpendicular to the y-axis; thus the efficiency approaches that of a one-dimensional integration. Even though the integration grid must be rotated to obtain the pattern in other planes, the required grid rotation is computationally much faster than the numerous two-dimensional integrations that would otherwise be required.

The reflector code requires approximately 250 Kbytes of storage. Typical CPU times for far field results are less than 1 second per pattern angle on the ElectroScience Laboratory Datacraft computer. For example the patterns in Figure 9 require about 300 seconds each of CPU time to give a printout for 361 pattern values ($\Delta\theta=0.5^{\circ}$). The corresponding CPU time for Figure 15 is about 210 seconds.

Since NF computations by AI are done by two-dimensional integrations, the CPU times depend greatly on the aperture size in wavelengths. Typical CPU time for the patterns of the 22λ diameter circular reflector shown in Figures 19 and 20 is about 5 seconds per pattern angle for AI and 2 seconds per pattern angle for GTD. The CPU times for GTD are nearly independent of aperture size. The code is expected to run 3 to 5 times faster on machines comparable to a CDC-6600.

The capabilities of the code may be summarized as follows:

1. A general reflector rim shape may be used (piecewise linear).

2. The required input data for the feed pattern is minimized by piecewise linear pattern fitting.

3. Storage and computation time of aperture data for AI is minimized by using a principal rectangular grid and interpolation of the aperture field.

4. The efficiency of field computations is maximized by the use of GTD for wide pattern angles and the use of the rotating grid method for far field computations at small angles (main beam region). The more efficient GTD is used even for small angles at close range in the near field.

5. The feed may be linearly polarized with any orientation or circularly polarized.

The GTD and AI approaches used for the code have a basic limitation on the minimum size reflector that can be modeled. This limitation is probably on the order of 1λ to 3λ for the reflector diameter. However, virtually all practical reflector antennas exceed 3λ diameter. There is no basic limitation on the maximum size of the reflector for the basic analysis. In the code, the reflector surface is assumed to be a perfect paraboloid. Thus, an actual reflector antenna must have sufficiently good tolerances, especially at high frequencies, so that it can be accurately modeled by the code.

The practical limitations on this version of the code can be summarized as follows:

1. The feed must be located at the focus and have a constant phase pattern.

2. The reflector surface must be paraboloidal.

3. Strut scattering effects are not included.

4. The grid size used for aperture integration must be chosen sufficiently small to give a good representation of the aperture field distribution.

5. Array variables associated with the rim data, the principal grid and the feed pattern must be given sufficient dimensions for the required input data.

Several statements are included in the code to print out a warning message if the declared dimension is exceeded for certain array variables. This has been done for the variables mentioned in item 5 above.

II. OUTPUT FROM THE CODE

For far field calculations or for near field calculations with constant range, the total field is converted to principal and cross polarized components as referred to the polarization of the field components from a Huygen's source [2]. For near field calculations with constant z, the field is still expressed in rectangular components.

Far field calculations can be made with or without the e^{-jkR}/R range factor and this is controlled by the input logical variable LRANG. If the range factor is suppressed (LRANG=false) the dB output of the code is expressed as antenna gain relative to isotropic.

For far field calculations including the range factor (LRANG=true) or for near field calculations the output is expressed as the electric field relative to the field level of the feed along its axis and at

a range equal to the focal distance of the reflector. In cases for which the feed axis is aligned with the reflector axis (zero feed tilt angle) this field reference is the aperture field at the center of the aperture. Thus the power density (based on free space impedance) for these cases can be calculated from

$$S = \frac{P_T |E|^2}{F^2 P_{rad}}$$

where

$|E|$ = magnitude output of the code
P_T = transmitter power (radiated)
F = focal length of the reflector
P_{rad} = relative power radiated by the feed

The information for F and P_{rad} are included in the variable

$$REFDB = 10 \log \frac{4\pi\lambda^2}{F^2 P_{rad}}$$

This variable is used to calculate far field gain and is given as output from the code. Thus the power density in dB relative to 1 Watt/meter^2 (assuming P_T is watts and λ is meters) is given by

$$S_{dB} = 20 \log|E| + REFDB + 10 \log \frac{P_T}{4\pi\lambda^2}$$

III. APPLICATIONS OF THE CODE

The reflector code can be used for the following basic applications:

1. Pattern prediction of existing reflector antennas.

2. Reflector antenna design.

3. Radiation hazard calculations.

4. EMC or coupling calculations with small antennas.

The far field capability of the code is used for applications 1 and 2 listed above. For pattern prediction it is necessary to have sufficient information about the reflector dimensions and feed pattern. For antenna design the code can be used in an iterative manner to seek a practical design having a given pattern performance goal. Or, the code can be used to give a more accurate prediction of the performance of a design obtained from more approximate techniques.

The near field capability of the code can be used for EMC and radiation hazard applications. The code can accurately calculate the field at virtually any point that is at least one diameter from the reflector.

Since the code is efficient even for near field computations it eliminates the necessity to rely entirely on approximate techniques as has usually been done in the past.

For radiation hazard applications the code is used to calculate the level of the electric field or the power density at the near field point. For EMC or coupling calculations the power density incident on a small antenna is first calculated using the code; then the coupling is calculated by multiplying by the effective aperture of the small antenna. Thus the power received by a small antenna is given by

$$P_R = S \frac{\lambda^2}{4\pi} G_R$$

where G_R is the appropriate gain of the small antenna. The coupling between the reflector antenna and the small antenna can be expressed as

$$\left(\frac{P_R}{P_T}\right)_{dB} = 20 \log|E| + \text{REFDB} - 20 \log(4\pi) + (G_R)_{dB} .$$

IV. PRINCIPLES OF OPERATION

A command word system is used to input data into the code. By this method additional computer runs can be made by making small changes in the input data. A block diagram for the command word system is shown in Table I. As seen in the table the code can be run by using default data stored in the code (NX: Command). This is useful for initial testing of the code. Also, the default data can be changed as desired by the user to represent a commonly used reflector antenna. Various test options (TO: Command) are available for testing and debugging the code. The input patterns of the feed antenna are specified by the desired number of ϕ-pattern cuts. The input pattern data is controlled by the FD: Command. The feed pattern may be specified either by sample feed data points or as analytic functions. The reflector geometry and dimensions are specified by the DG: Command. The rectangular grid size to be used for aperture integration is also specified by the DG: Command. A do loop for operating frequency is controlled by the FQ: Command so that the code can be run for different frequencies without changing any other input data. This is useful if the feed pattern can be assumed not to change with frequency. If the feed pattern changes with frequency the feed command (FD:) must be used before the code is executed at each new frequency. The NF: Command controls whether near field or far field output is computed. It also specifies the origin and the ϕ-plane cut for near field results. Detailed information on the output pattern cuts is controlled by the PZ: command for either near field or far field computations. Either evenly spaced pattern cuts or unevenly spaced cuts (up to 10) can be specified. The LP: and PP: Commands provide for line printer and pen plotter outputs, respectively. Com-

ments can be printed on the output data by using the CM: Command. The TL: Command is used to specify the tilt angle of the feed axis and the aperture center for offset reflectors.

Most of the far field pattern calculations are performed in terms of the E_θ and E_ϕ components; but they are then converted to principal and cross polarized components for the output pattern. A Huygen's source representation is used as a reference for the principal and cross polarizations [2]. Most of the near field calculations are performed in rectangular field components. After all pattern calculations have been completed for the specified ϕ-plane cuts and the specified frequencies, the code returns for the next command word. The theory and algorithms of the code are documented in the code manual [1].

TABLE I
BLOCK DIAGRAM OF THE INPUT FOR THE REFLECTOR CODE

For Command Word Input Refer to Section and Page Number Cited Below

START

Command	Section	Page
NX: Command Read Default Data	A	9
DG: Command Read Reflector Geometry Data	B	9
TO: Command Read Test Data	C	12
FD: Command Read Feed Pattern Data	D	16
FQ: Command Read Frequency Data	E	21
NF: Command Specify Near or Far Fields	F	21
PZ: Command Read Output Pattern Data	G	25
LP: Command For Line Printer Output	H	27
PP: Command For Pen Plotter Output	I	27

CM: or CE: Command For Comments on Output Listing	J	27
TL: Command Read Data for Offset Reflectors	K	28
XQ: Command Execute Program	L	29
After Data Output Return for Next Command Word		

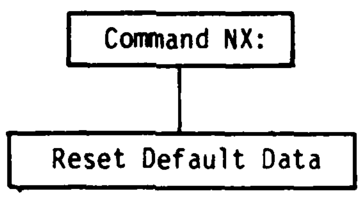
V. COMMAND WORD SYSTEM

The method used to input data into the computer code is based on a command word system. This is especially convenient when more than one problem is to be analyzed during a computer run. The code stores the previous input data such that one need only input that data which needs to be changed from the previous execution. Also, there is a default list of data so for any given problem the amount of data that needs to be input has been shortened. The following list defines in detail each command word and the variables associated with them. A table is given with a block diagram for each command word that shows the way to input the data associated with that command.

A. Command NX: (Refer to Table 2)

This command resets the input data of the code to that of the default case. Thus the user can read this command word followed by the XQ: Command to run the default case at any time. This command is always executed at the beginning of a run. Consequently, all input data will correspond to the default data except that which is changed by another command. The default case can be run as the first case by a single XQ: Command word.

TABLE 2
BLOCK DIAGRAM FOR DEFAULT DATA



B. Command DG: (Refer to Table 3)

This command enables the user to specify the shape and dimensions of the parabolic reflector, and also the rectangular grid size to be used for aperture integration. All units are specified according to the value of IUNIT.

1. READ: INUIT, F,GRIDX,GRIDY,D

   a) IUNIT; This is an integer variable that indicates the units for the input data as follows:

   1→meters
   IUNIT 2→feet
   3→inches.

b) F: This is a real variable which defines the focal distance of the parabola.

c) GRIDX,GRIDY: These are real variables which define the rectangular grid dimensions, D_x and D_y, as shown in Figure 1. The rectangular grid is used for aperture integration and thus its size must be sufficiently small to provide a reasonable piecewise linear representation of the aperture field distribution. However, the grid dimensions may be large in wavelengths.
The grid dimensions D_x and D_y together with the aperture size control the maximum number of grid lines I_{max}, J_{max} used for aperture integration. At least 3 grid lines must be used in the code.
Presently $3 \leq I_{max} \leq 48$

$3 \leq J_{max} \leq 48$.

Note that more grid lines are required when the rotating grid is used for off principal plane cuts. Approximately 50% more grid lines are required for ϕ-cuts near 45^o and odd multiples of 45^o.

d) D: This is a real variable which defines the diameter of the reflector. If the diameter is read as a positive value (D>0), the reflector is assumed to be circular and the code generates the rim points. If diameter is zero or negative (D≤0.), a general rim shape may be read with the following read statement.

2. READ: NRIM,((RIM(NE,N),N=1,2),NE=1,NRIM)

This statement is skipped if D>0.

a) NRIM: This is an integer variable which defines the number of input rim points.
Presently $3 \leq NRIM \leq 64$.

b) RIM(NE,N): This is a doubly dimensioned real variable. It is used to specify the location of the NE^{th} corner of the projected piecewise linear aperture rim as shown in Figure 1. It is input on a single line with the real numbers being the x, y coordinates of the corner which correspond to N=1,2, respectively, in the array.

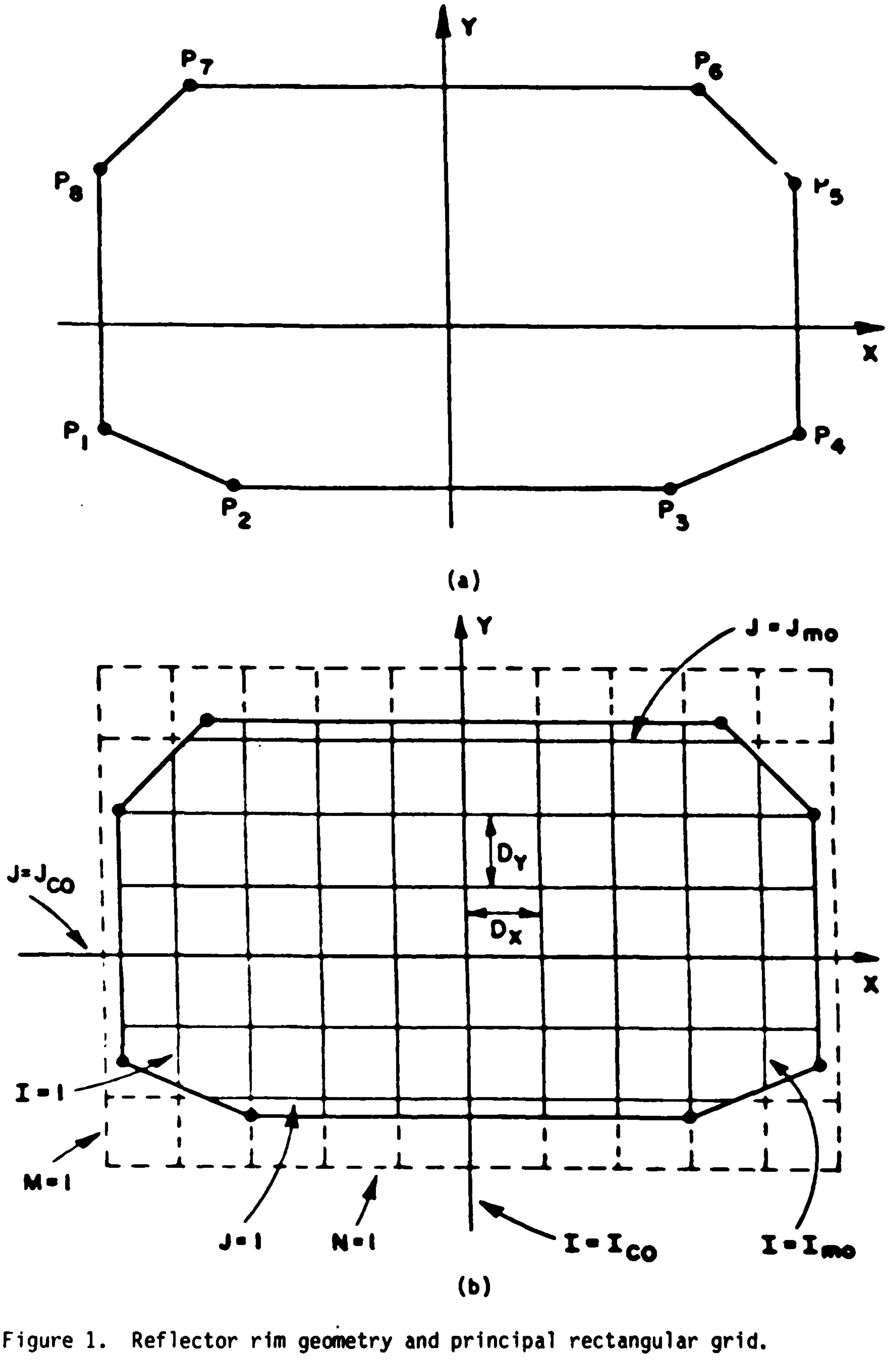
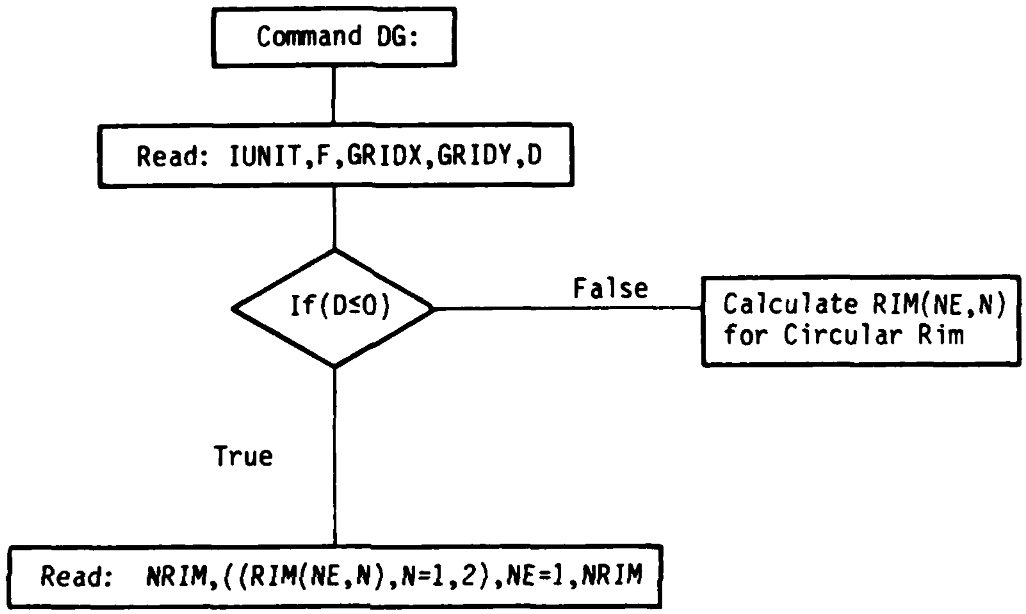


Figure 1. Reflector rim geometry and principal rectangular grid.

TABLE 3
BLOCK DIAGRAM FOR REFLECTOR GEOMETRY



C. Command TO: (Refer to Table 4)

This command enables the user to obtain an extended output of various intermediate quantities in the computer code. This is useful in testing the program or in analyzing the contributions from various scattering mechanisms in terms of the total solution.

TABLE 4
BLOCK DIAGRAM FOR TEST OPTIONS

Command TO:

Read: LDEBUG,LTEST,LWYSUM,LOUT,LWFD

Read: LSLOPE,LCORNR

Read: LAI,LFEED,LGTD,THETAX,ZXP

1. READ: LDEBUG,LTEST,LOUT,LWFD

a) LDEBUG: This is a logical variable defined by T or F. It is used to debug the program if errors are suspected within the program. If set true, the program prints out data on unit #6 associated with each of its internal operations. These data can, then, be compared with previous data which are known to be correct. It is also used to insure initial operation of the code. Only one pattern angle is usually considered. (normally set false)

b) LTEST: This is a logical variable defined by T or F. It is used to test key variables in the code such as the input/output associated with each subroutine. The data written out on unit #6 are associated with the data in the window of the subroutine. They are written out each time the subroutine is called. It is, also, used to insure initial operation of the code. Only one pattern angle is considered. (normally set false)

c) LWYSUM: This is a logical variable defined by T or F. It is used to output data about the aperture field and the partial sums of the aperture integration including the y-integration YSUM data. This data is controlled separately from that controlled by LDEBUG or LTEST because of the large amount of output. (normally set false)

d) LOUT: This is a logical variable defined by T or F. It is used to output data on unit #6 associated with the main program. It too is used to initially insure proper operation. It can be used to examine the various components of the pattern. (normally set false)

e) LWFD: This is a logical variable defined by T or F. It is used to tell the code whether or not to calculate and output data for the feed pattern. (normally set true)

2. READ: LSLOPE,LCORNR

a) LSLOPE: This is a logical variable defined by T or F. It is used to tell the code whether or not slope diffraction is desired during the computation. (normally set true)

b) LCORNR: This is a logical variable defined by T or F. It is used to tell the code whether or not corner diffraction is desired during the computation. (normally set true)

3. READ: LAI,LFEED,LGTD,THETAX,ZXP

a) LAI: This is a logical variable defined by T or F. It is used to tell the code whether or not aperture integration is to be used in computing the pattern. If set false only GTD can be used for the contribution from the reflector. (normally set true)

b) LFEED: This is a logical variable defined by T or F. It is used to tell the code whether or not the primary feed pattern spillover is desired during the pattern computation. (normally set true)

c) LGTD: This is a logical variable defined by T or F. It is used to tell the code whether or not GTD is to be used in computing the pattern. If set false only aperture integration can be used for the contribution from the reflector. (normally set true)

d) THETAX: This is a real variable input in degrees. It is used as a criterion for switching from AI to GTD for both far field and near field calculations. If the field point angle $|\theta|$<THETAX, AI is used; otherwise, GTD is used.

e) ZXP: This is a real variable input in the unit specified by the variable IUNIT in the DG: Command. It is used as a range criterion only for near field calculations. If the range R (LRANG=true) or the distance from the aperture Z (LRANG=false) is less than ZXP, only GTD is used. Other wise, the near field point angle is compared with THETAX to determine if AI or GTD is used.

If both THETAX and ZXP are input as zero, they will be calculated as follows:

$$\text{THETAX}=\theta_x = \sin^{-1}\frac{1}{\sqrt{A_w}}$$

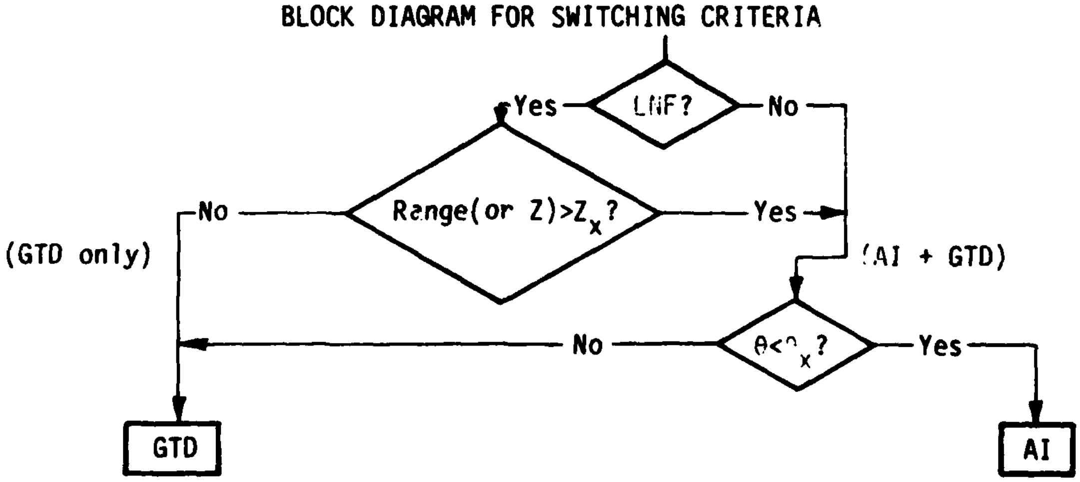
and

$$\text{ZXP}=Z_x = \frac{A_w}{2\tan\theta_x}$$

where A_w is the aperture width in the specific pattern cut.

The usage of the above criteria is summarized in Table 5.

TABLE 5
BLOCK DIAGRAM FOR SWITCHING CRITERIA



D. <u>Command FD:</u> (Refer to Table 6)

This command enables the user to specify the feed pattern.

1. READ: LLFD,LCP,LDB,ISYM,TAU

a) LLFD: This is a logical variable defined by T or F. It is used to tell the code whether or not a piecewise linear feed pattern is to be used. If set false an analytic function is used.

b) LCP: This is a logical variable defined by T or F. It is used to tell the code whether or not the feed is circularly polarized. If set false linear polarization is used.

c) LDB: This is a logical variable defined by T or F. It is used to tell the code whether or not the feed pattern input and output data are specified in dB or not. If LDB is false, feed pattern input and output are linear field values.

d) ISYM: This is an integer variable which defines the type of symmetry for the feed pattern. Positive values are used for even symmetry (sum patterns) and negative values are used for odd symmetry (difference patterns). The absolute value (IB= |ISYM|) defines the regions of symmetry with respect to the feed coordinate system (x,y,z) shown in Figure 2.
IB=0: No symmetry
IB=1: Symmetry with respect to x and y axes
IB=2: Symmetry with respect to x axis
IB=3: Symmetry with respect to y axis.

e) TAU: This is a real variable. It is input in degrees and defines the linear polarization angle relative to the x-axis of the feed as shown in Figure 2(b). TAU=0 for horizontal polarization, and TAU=90 for vertical polarization.

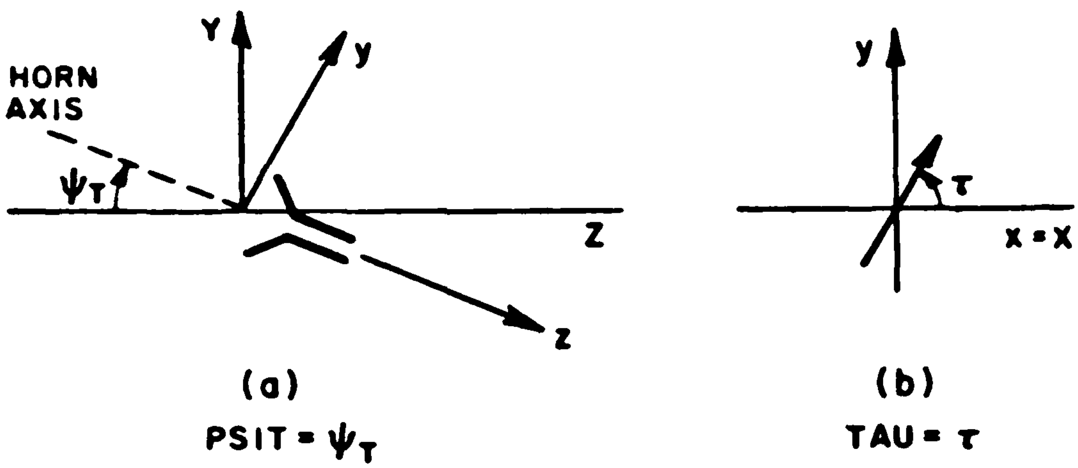


Figure 2. Coordinate system of feed horn and polarization angle when linearly polarized.

2. READ: NPHI, (PHIN(N),N=1,NPHI)

a) NPHI: This is an integer variable which defines the number of input feed pattern cuts. Each input pattern corresponds to a ϕ-plane cut with respect to the feed axis (same as reflector axes for PSIT=0.)

b) PHIN(N): This is a dimensioned real variable. It is input in degrees and defines the ϕ_n angle of the N-th pattern cut as shown in Figure 3. The values must be input in monotonic order, i.e., PHIN(N+1)> PHIN(N). The first value N=1 and the last value N=NPHI must be consistent with the type of pattern symmetry as shown below:

IB=|ISYM|	Type of Symmetry	PHIN(1)	PHIN(NPHI)
0	None	-180^o	-
1	x&y axes	0^o	90^o
2	x-axis	0^o	180^o
3	y-axis	-90^o	90^o

For a feed pattern with no ϕ-symmetry (ISYM=0) the -180^o pattern cut is also automatically stored as the $+180^o$ pattern cut. Presently $1 \leq N \leq 15$.

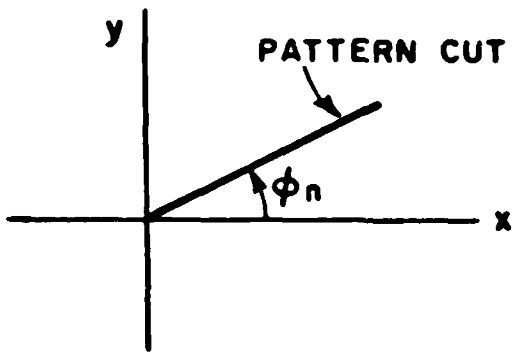


Figure 3. N-th input feed pattern cut, PHIN(N)=ϕ_n.

3. READ: NPW,(AEX(N),CAN(N),PSIO(N),N=1,NPHI)

This statement is used to specify the analytic pattern (LLFD=false). The analytic functions are described in Appendix I. This read statement is skipped if LLFD=true.

a) NPW: This is an integer variable which defines the power for the cosine or sine function.

b) AEX(N),CAN(N),PSIO(N): These are dimensioned real variables which define the analytic pattern in the N-th Φ-pattern cut. Presently $1 \leq N \leq 15$.

4. READ: N2

This read statement is skipped if LLFD=false.

a) N2: This is an integer variable which defines the maximum number of feed pattern points to be read for all input ϕ-plane pattern cuts. It is used only for piecewise linear feed pattern input (LLFD=true). Presently $2 \leq N2 \leq 15$.

5. READ: PXI(K),FN

This read statement is skipped if LLFD=false.

a) PSIX,FN: These are real variables which define the piecewise linear feed input pattern for the K-th angle PSIX=ψ_k as shown in Figure 4. FN=f(ψ_k) is the pattern value (in dB for LDB true, or linear field value for LDB false). Presently $1 \leq K \leq 15$.

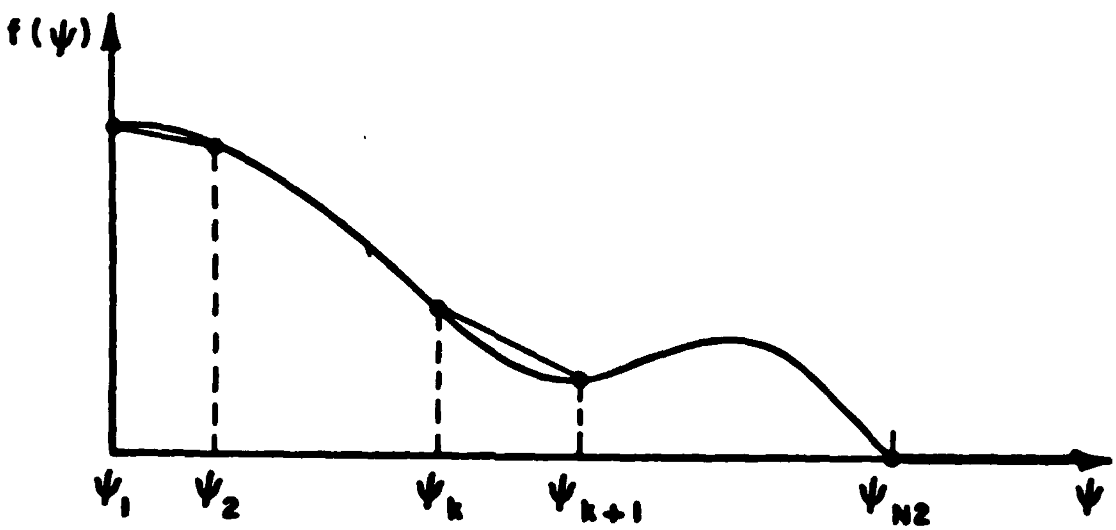
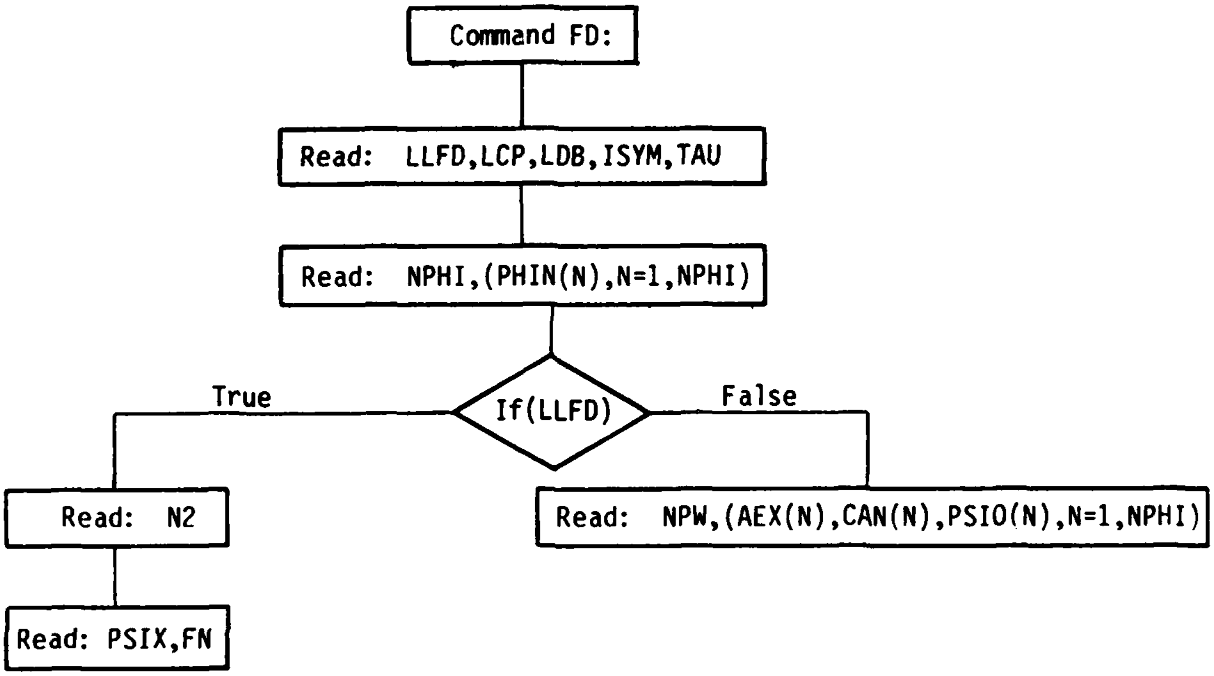


Figure 4. Piecewise linear approximation for feed patterns.

TABLE 6
BLOCK DIAGRAM FOR FEED PATTERN



E. Command FQ: (Refer to Table 7)

This command enables the user to specify the frequencies for which patterns are to be computed.

1. READ: NFRQ,(FREQ(I),I=1,NFRQ)

a) NFRQ: This is an integer variable used to define the number of frequency inputs. If the feed is frequency dependent NFRQ=1; and only one input frequency FREQ(1) is used in conjunction with a new input feed pattern for each frequency, using the FD: Command.
Presently $1 \leq NFRQ \leq 10$.

b) FREQ(I); This is a dimensioned real variable which defines the I^{th} frequency for which a given antenna design with a frequency-independent feed pattern is to be run.

TABLE 7
BLOCK DIAGRAM FOR FREQUENCIES

Command FQ:
Read: NFRQ,(FREQ(I),I=1,NFRQ

F. Command NF: (Refer to Table 8)

This command enables the user to specify whether near field or far field output is to be computed. It also specifies the ϕ-plane cut and coordinate origin for near field calculations as shown in Figure 5b. The units for the distance parameters are specified according to the value of

$$IUNIT = \begin{cases} 1 \rightarrow \text{meters} \\ 2 \rightarrow \text{feet} \\ 3 \rightarrow \text{inches.} \end{cases}$$

The value of IUNIT is controlled by the DG: Command.

1. READ: LNF,LRANG

a) LNF: This is a logical variable specified by T or F. It is used to tell the code whether or not near field output is to be computed. If set false far field patterns are computed.

b) LRANG: This is a logical variable specified by T or F. For far field output it specifies whether the range factor e^{-jkR}/R is to be included. If set false the range factor is suppressed. For near field output it specifies whether results for a given ϕ_E-plane cut (PHIE) are to be computed for constant range R or constant Z distance. If set false results are calculated for a constant Z distance from the aperture plane. See Figure 5.

2. READ: RANG

This statement is skipped if LNF=true or LRANG=false.

a) RANG: This is a real variable which defines the far field range R at which the antenna fields are to be calculated as shown in Figure 5a. It is used only when LRANG=true and LNF=false.

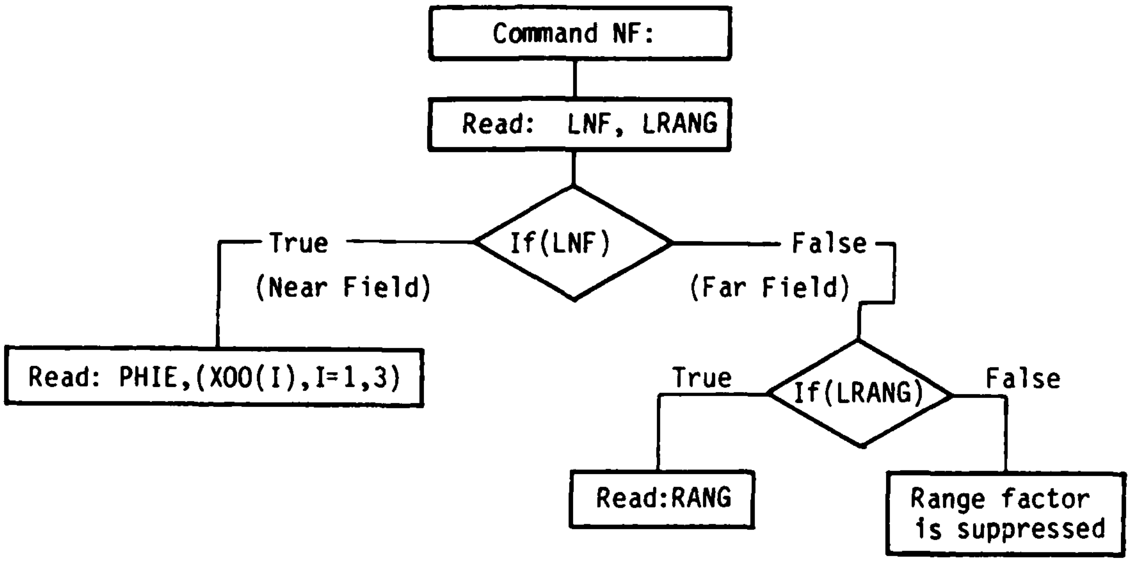
3. READ: PHIE, (XOO(I),I=1,3)

This statement is skipped if LNF=false.

a) PHIE: This is a real variable. It is input in degrees and defines the ϕ-plane cut for near field output as shown in Figure 5b.

b) XOO(I): This is a dimensioned real variable. It is used to specify the origin of the coordinate system for near field observation points. See Figure 5.

TABLE 8
BLOCK DIAGRAM FOR NEAR FIELD/FAR FIELD OPTIONS



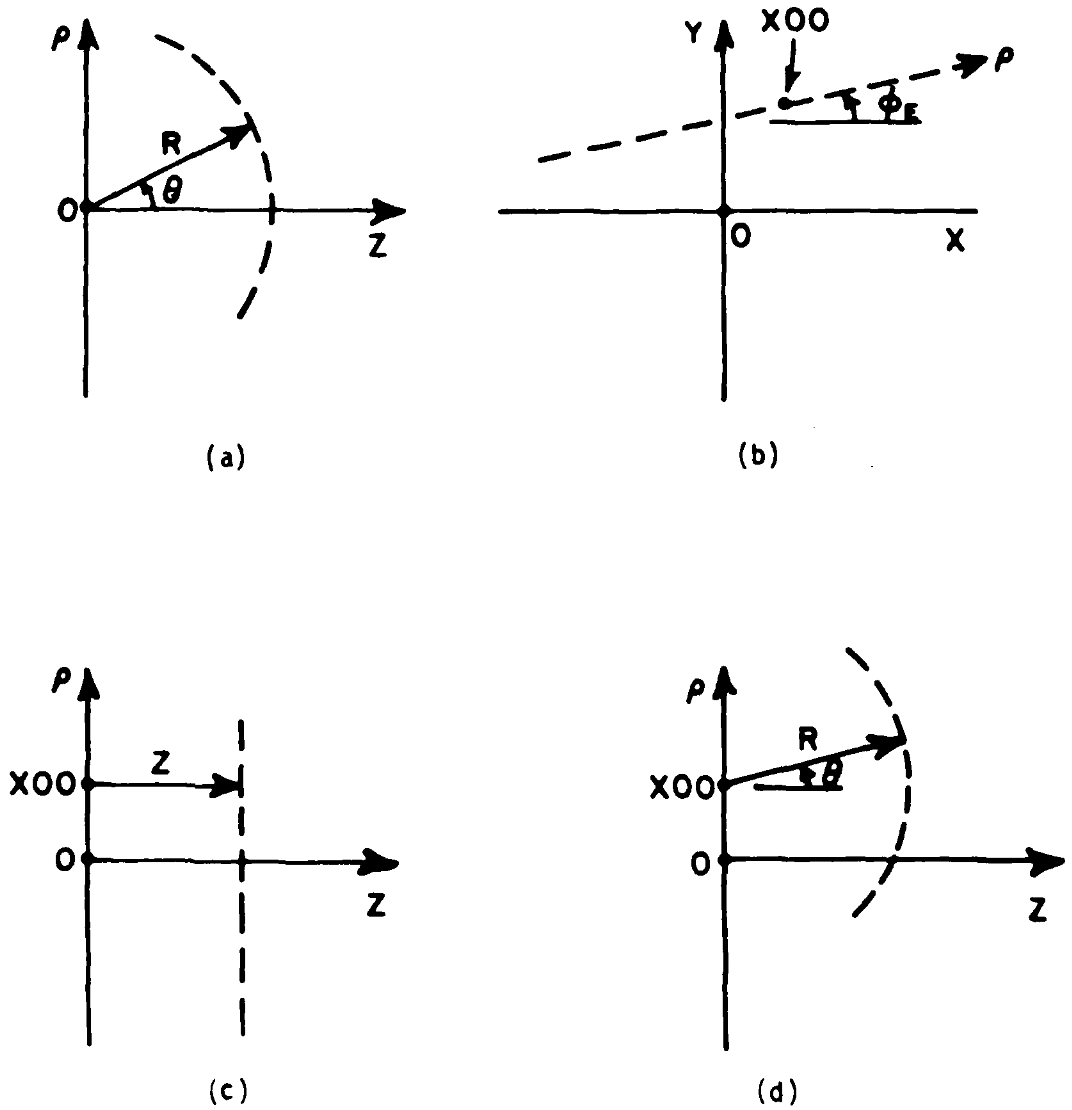


Figure 5. Coordinate systems for far field and near field pattern cuts.

G. *Command PZ:* (Refer to Table 9)

This command enables the user to specify the output data. For far field patterns (LNF=false) this command specifies the ϕ-plane pattern cuts and the initial, final and incremental values for the pattern angle ϕ. For near field computations this command specifies the constant R-cuts (LRANG=true) or constant Z-cuts (LRANG=false) for which the fields are to be computed. The output pattern parameters R, θ, ϕ, ρ and z are shown in Figure 5. The units for the distance parameters are specified according to the value of

$$\text{IUNIT} = \begin{cases} 1 \rightarrow \text{meters} \\ 2 \rightarrow \text{feet} \\ 3 \rightarrow \text{inches.} \end{cases}$$

The value of IUNIT is controlled by the DG: Command.

The following read statements control the output pattern parameters by use of the variables P2 and P3 as given in Table 10.

1. READ: IP2

   a) IP2: This is an integer variable which is used to specify the number of pattern cuts for the output data for each frequency. Its absolute value NP2=|IP2| is the number of pattern cuts to be calculated.
   Presently $1 \leq |IP2| \leq 10$.
   If IP2 is positive (IP2>0), unevenly spaced - increments can be used as follows:

2. READ: (AP2(L),L=1,NP2)

   a) AP2(L): This is a dimensioned real variable which defines the L^{th} value of P2 for output pattern data. This read statement is used only for IP2>0. Presently $1 \leq L \leq 10$.

3. READ: (AP2(L)L=1,2)

   This read statement is used for negative values of IP2(IP2<0); then, <u>evenly</u> spaced ϕ-increments are used as follows:

   a) AP2(L): This is a dimensioned real variable. AP2(1) is the initial value of P2 for the output pattern data. AP2(2) is the P2 increment for the output pattern data.

4. READ: AP3I,AP3F,ADP3

a) AP3I: This is a real variable which defines the initial value of P3 for each pattern cut.

b) AP3F: This is a real variable which defines the final value of P3 for each pattern cut.

c) ADP3: This is a real variable which defines the value by which P3 is to be incremented for the output pattern.

TABLE 9
BLOCK DIAGRAM FOR OUTPUT PATTERN CUTS

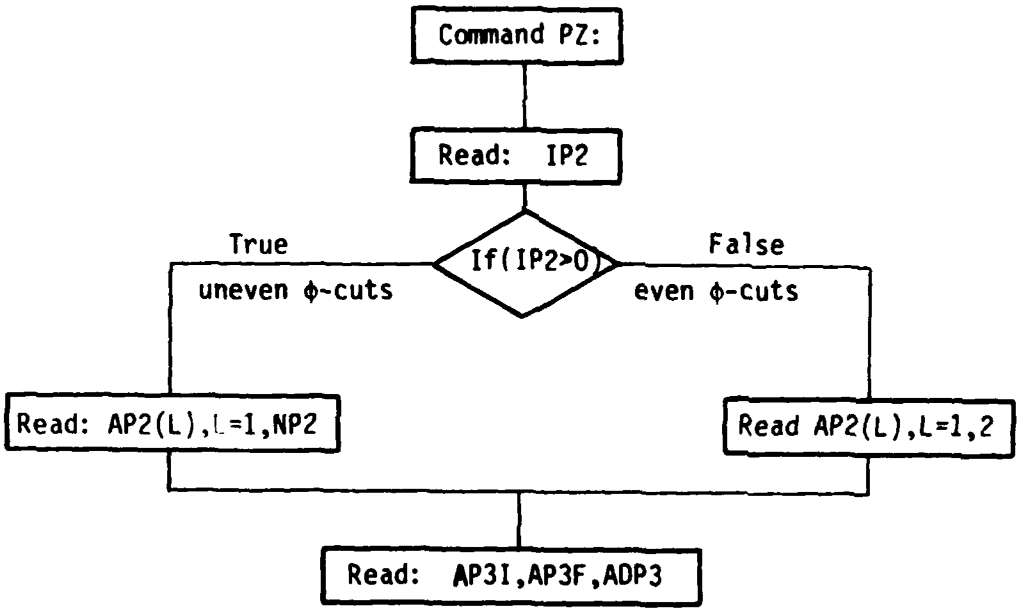


TABLE 10
USE OF VARIABLES P2 AND P3

	P2	P3
Input Variables	AP2(L)	AP3I,AP3F,ADP3
Far Field (LNF=false)	ϕ	θ
Near Field* Constant-R (LRANG=true)	R	θ
Near Field* Constant-Z (LRANG=false)	Z	ρ

*For near field computations the ϕ-plane cut is defined by PHIE as specified by the NF: Command.

H. Command LP:

This command enables the user to specify whether a line printer listing of the results is desired. It sets a flag so that data will be written out on a line printer.

I. Command PP:

This command enables the user to specify whether plotted data is desired.

J. Command CM: or CE: (Refer to Table 11)

This command enables the user to write comments along with the output data of the code. If the CM: command is input, comment cards can then be read and the corresponding comments will be written as part of the code output. Each comment card except the last in a sequence must have "CM:" for its first three characters. The last comment card in the sequence must have "CE:" for its first three characters; then the code returns for another possible command word.

1. READ: IR(I) I=1,24

IR(I): This is a dimensioned array of up to 72 typed characters (assuming 3 characters per word) which compose the desired comment. As stated before, the first three characters must be "CM:" for all comment cards except "CE:" for the last comment card in the sequence.

TABLE 11
BLOCK DIAGRAM FOR COMMENTS ON OUTPUT

Command CM: or CE:
Read: IR(I),I=1,24

K. <u>Command TL:</u> (Refer to Table 12)

This command enables the user to specify the tilt angle of the feed and the aperture center of the reflector on the Y-axis. This information is primarily useful for off-set reflectors.

1. READ: PSIT,YC

   a) PSIT: This is a real variable. It is input in degrees and defines the angle ψ_T by which the feed horn is tilted, in the y-z plane, from the negative z-axis, as shown in Figure 2(a).

   b) YC: This is a real variable. It is input in the units specified by the variable IUNIT and defines the aperture center of an off-set reflector antenna. It is particularly useful for circular rim shapes in which case the rim points are calculated from the reflector diameter D.

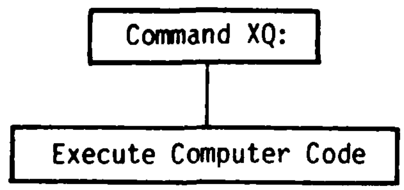
TABLE 12
BLOCK DIAGRAM FOR OFF-SET REFLECTORS

Command TL:
READ PSIT,YC

L. Command XQ:

This command is used to execute the reflector code so that the fields of the reflector may be computed and output. After execution the code returns for another possible command word.

TABLE 13
BLOCK DIAGRAM FOR EXECUTION



IV. APPLICATION OF CODE TO SEVERAL EXAMPLES

The following examples are used to illustrate the various features of the reflector code. Examples 1 through 3 show representative far field pattern calculations while examples 4 and 5 show near field calculations with constant range and constant z-cut, respectively. Note that the input data lists are shown containing most all of the commands needed for the particular examples given. In many cases the input list can be shortened because the data contained in the default list at the beginning of the program need not be input through the read statements every time. For example, the TO: Command data could be left out of the input list in most of the examples given here. The user should refer to the NX: Command to see what the defaults are. The default list can be changed to meet his particular needs if necessary.

Example 1. The first example is the common case of a circular reflector with an on-axis feed as shown in Figure 6. A GTD analysis was previously developed for the far field pattern of the circular reflector as reported in Reference 3. Calculated results are given in Reference 3 for a 24" diameter reflector with an F/D ratio of 1/3 and a frequency of 11 GHz. Thus this example can be used to verify the far field part of the reflector code.

The measured feed patterns for this antenna as given in Reference 3 are shown in Figure 7. The feed is linearly polarized in the y-direction. The piecewise linear feed pattern option of the reflector code was used to approximate the measured H- and E-plane feed patterns as shown in Figures 8a and b, respectively. The input data are given below:

```
DG:
3,8.,0.6,0.6,24.
TO:
F,F,F,F,F
T,T
1,T,T
0.,0.
FD:
T,F,F,1,90.
2,0.,90.
14
0.,1.
10.,0.9575
20.,0.8419
30.,0.684
40.,0.52
50.,0.3772
60.,0.2664
70.,0.1866
80.,0.1358
90.,0.10521
120.,0.03588
132.,0.05475
160.,0.01884
180.1,0.0224
0.,1.
10.,0.966
20.,0.8714
30.,0.7375
40.,0.59
50.,0.4522
60.,0.336
70.,0.2456
80.,0.1813
90.,0.13778
120.,0.0917
132.,0.079
170.,0.02114
180.,0.02427
PZ:
2
0.,90.
0.,180.,5.
FQ:
1,11.
XQ:
```

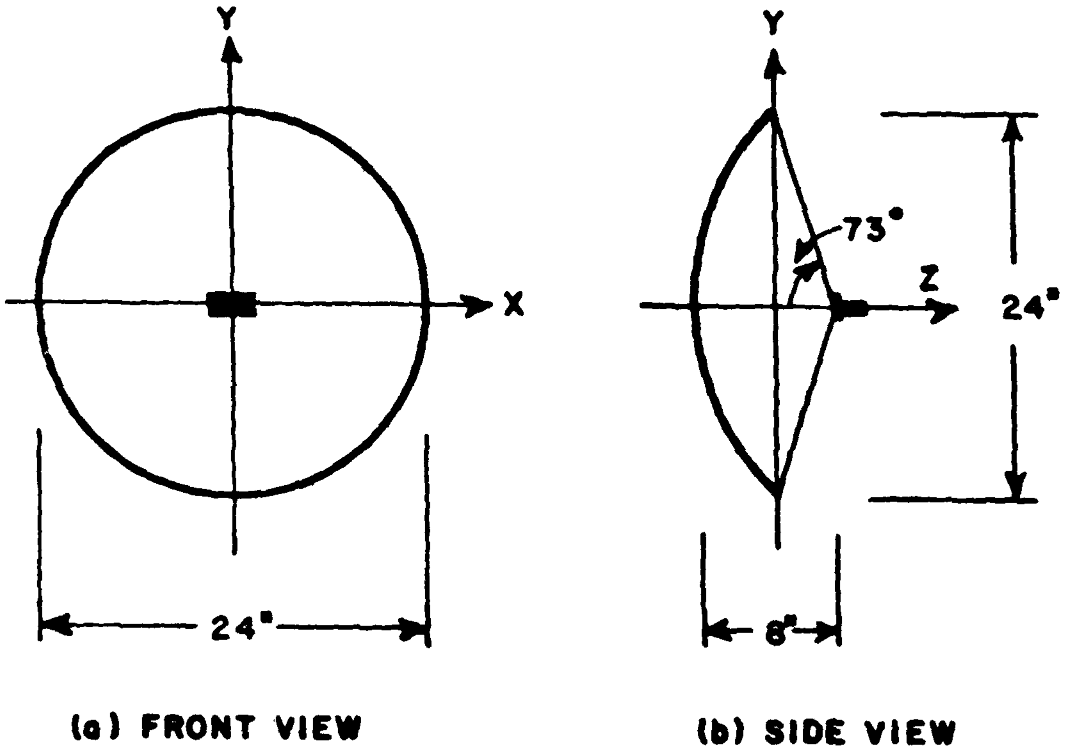


Figure 6. Circular reflector antenna with F/D = $\frac{1}{3}$.

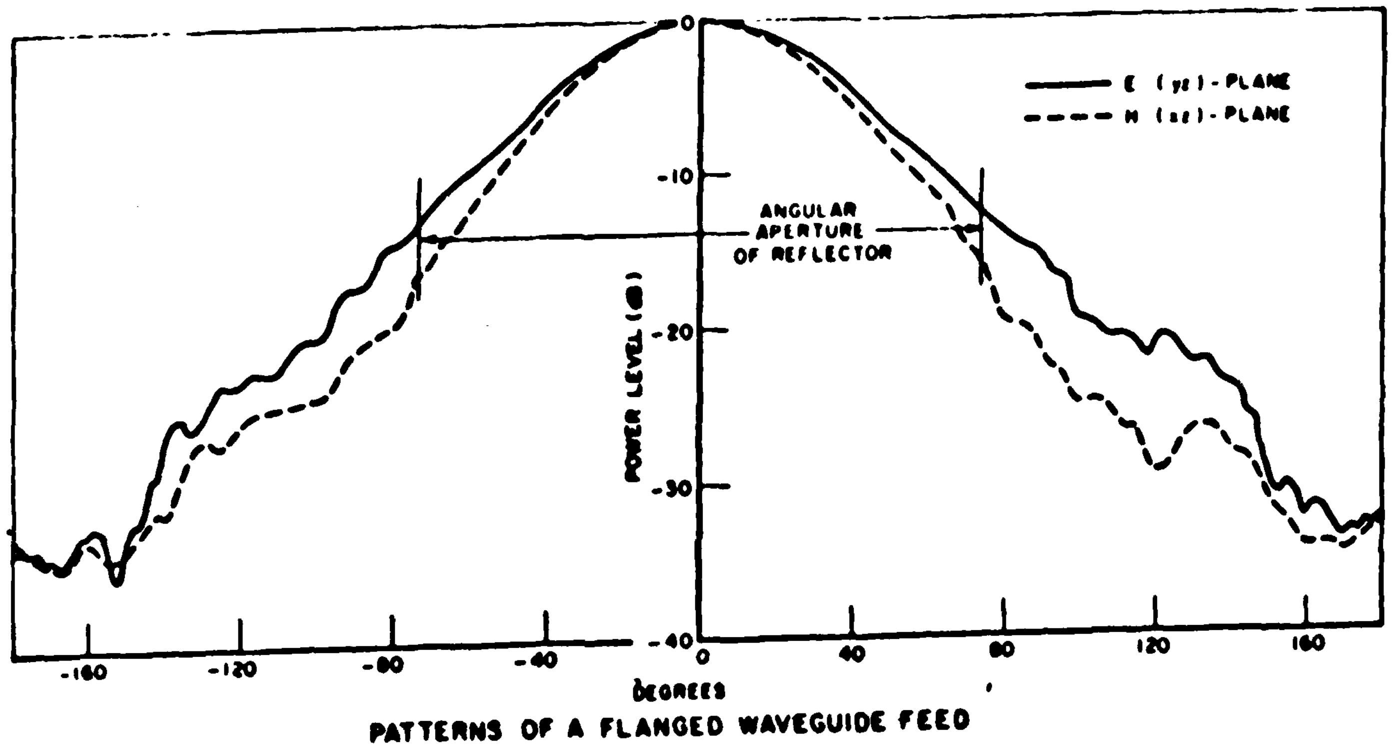
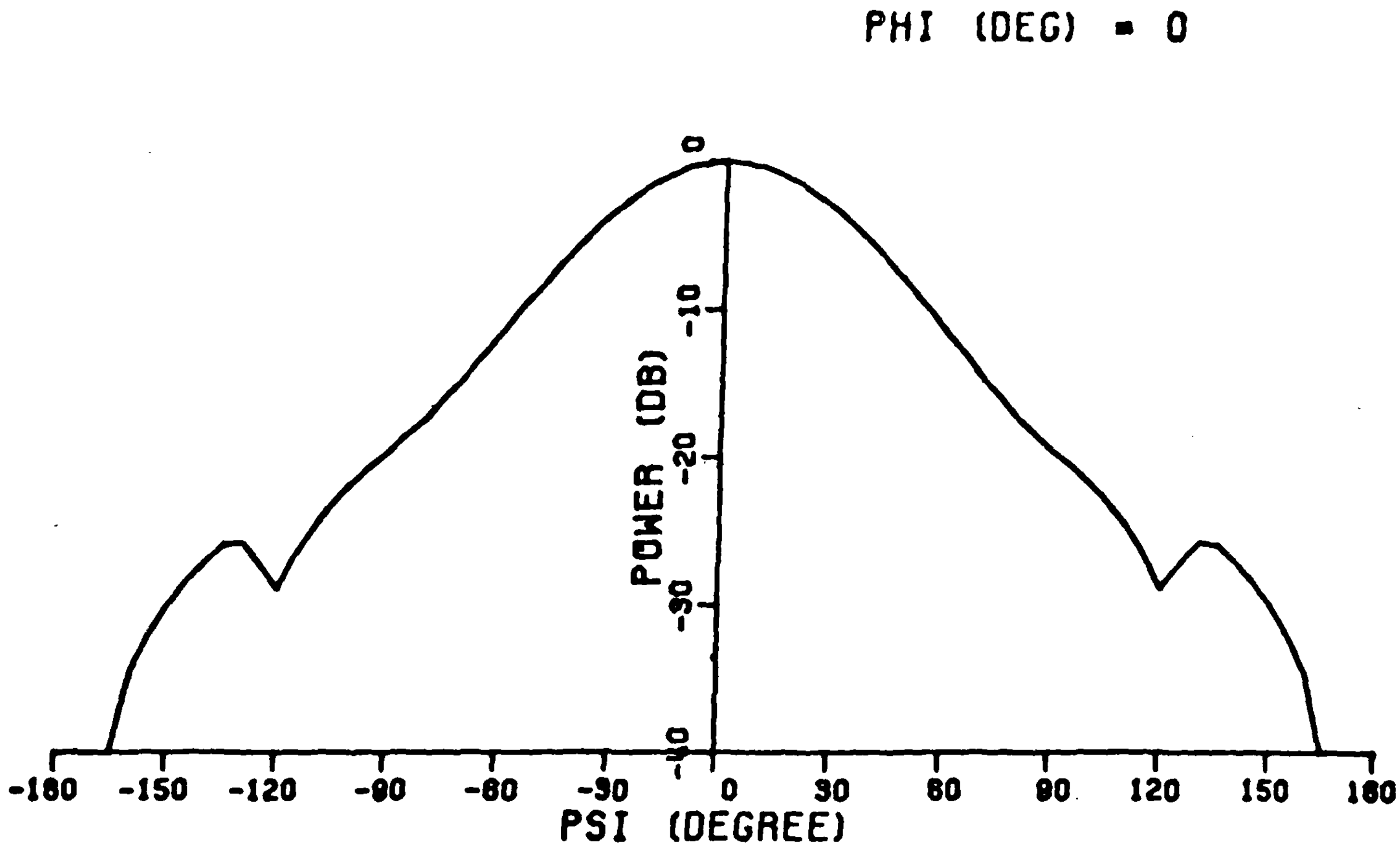


Figure 7. Measured primary field patterns of a flanged waveguide feed.



(a)

Figure 8. Input feed patterns for circular reflector example.

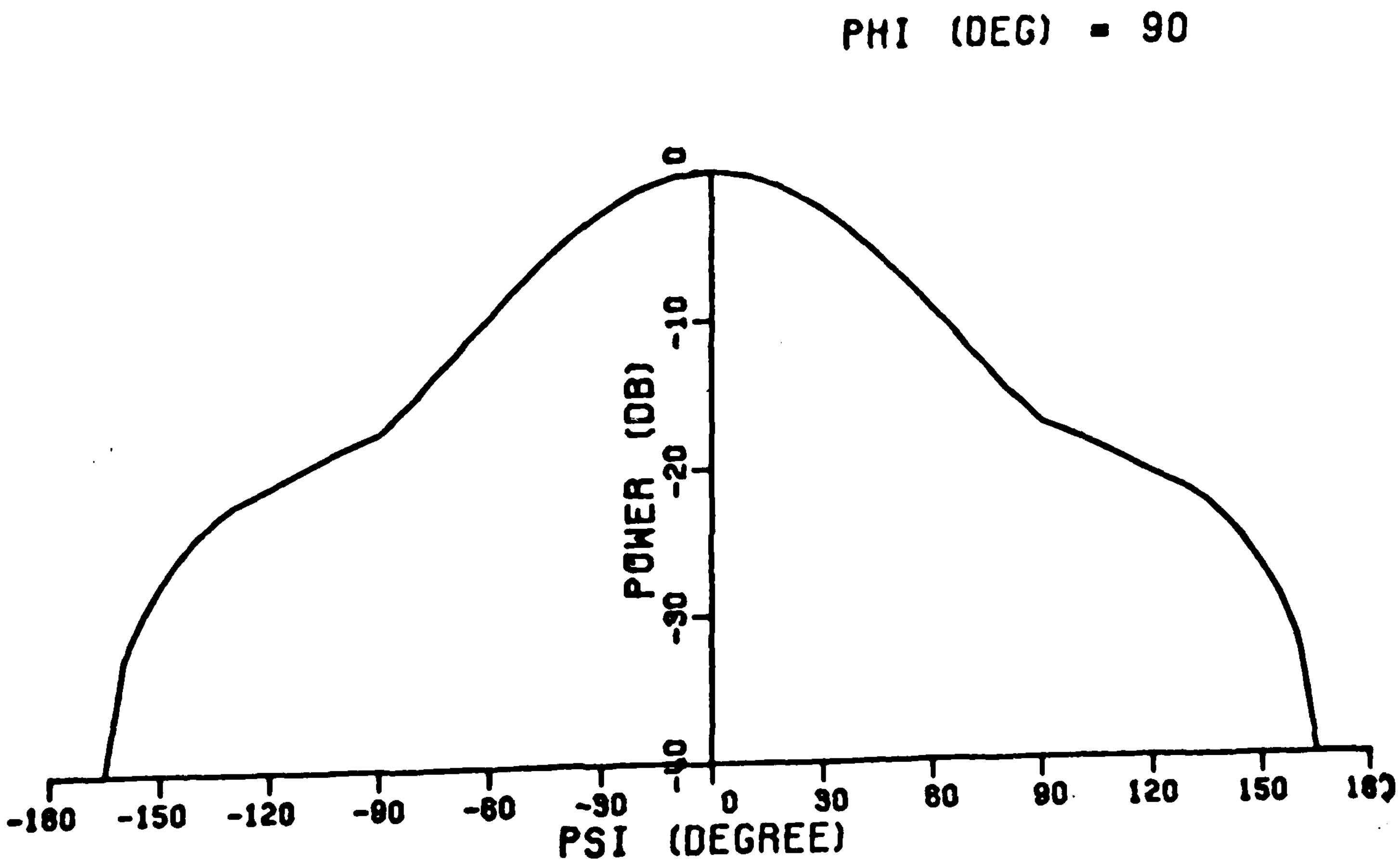


Figure 8. (Continued)

The output data for example 1 are given below. Note that a 5^o increment is used to give a course representation of the pattern output. Normally, about a $\frac{1}{2}^o$ increment would be used for complete pattern information in this example.

The far field patterns as computed by the general reflector code are shown in Figures 9a and b for the H-and E-planes, respectively. The results from the general reflector code were found to be in good agreement with the calculated results of Reference 3 without aperture blockage as shown in Figures 10 and 11. Aperture blockage and feed strut scattering effects have not yet been included in the general reflector code.

XQ:

PRAD = .131E 1

FREQUENCY = 11.000 GHZ

NUMBER OF RIM SEGMENTS=36

APERTURE DIAMETER = 22.35 WAVELENGTHS

COORDINATES OF RIM POINTS (WAVELENGTHS)

RIM POINT	X	Y
1	11.15	.98
2	10.82	2.90
3	10.15	4.73
4	9.17	6.42
5	7.92	7.92
6	6.42	9.17
7	4.73	10.15
8	2.90	10.82
9	.98	11.15
10	-.98	11.15
11	-2.90	10.82
12	-4.73	10.15
13	-6.42	9.17
14	-7.92	7.92
15	-9.17	6.42
16	-10.15	4.73
17	-10.82	2.90
18	-11.15	.98
19	-11.15	-.98
20	-10.82	-2.90
21	-10.15	-4.73
22	-9.17	-6.42
23	-7.92	-7.92
24	-6.42	-9.17
25	-4.73	-10.15
26	-2.90	-10.82
27	-.98	-11.15
28	.98	-11.15
29	2.90	-10.82
30	4.73	-10.15
31	6.42	-9.17
32	7.92	-7.92
33	9.17	-6.42
34	10.15	-4.73
35	10.82	-2.90
36	11.15	-.98

FOCAL DISTANCE = 7.45 WAVELENGTHS

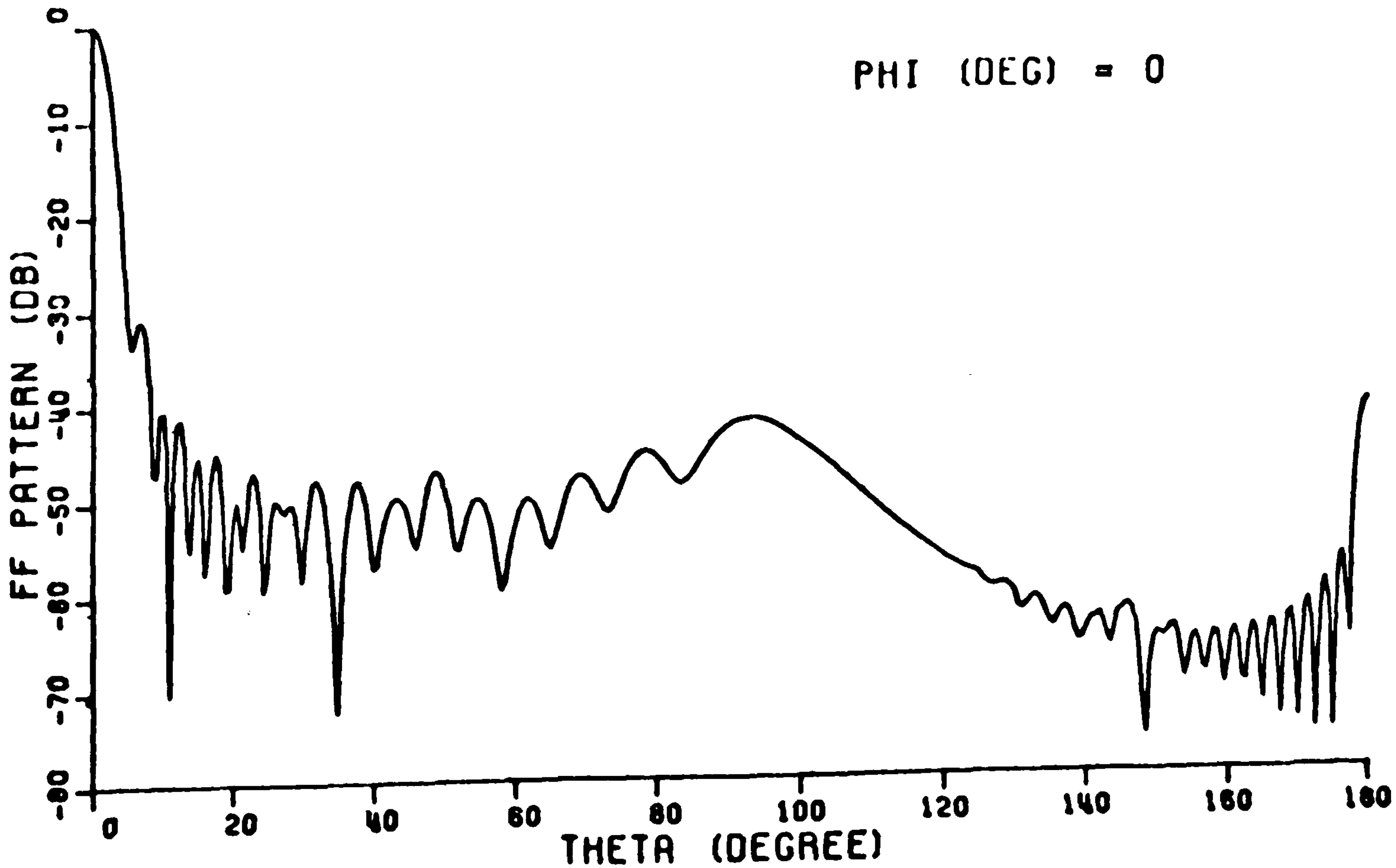
REFDB = -7.633

PHI - 0.00

THETA	MAG	DB	PHASE	MAG	DB	PHASE
0.00	138.5261	35.20	33.29	.0000	-139.52	33.29
5.00	3.8691	4.12	35.05	.0000	-170.59	34.69
10.00	1.1836	-6.17	-151.22	.0000	-181.04	-151.72
15.00	.6136	-11.88	-150.25	.0000	-187.08	-150.22
20.00	.3247	-17.40	-139.95	.0000	-191.95	-136.72
25.00	.1876	-22.17	-91.13	.0000	-95.52	63.28
30.00	.1656	-23.25	-50.79	.0000	-94.09	12.98
35.00	.0330	-37.27	-132.89	.0001	-87.64	-104.09
40.00	.1892	-22.09	170.05	.0001	-90.27	122.81
45.00	.3264	-17.36	144.88	.0001	-89.08	-40.82
50.00	.4900	-13.83	44.73	.0001	-89.50	138.26
55.00	.4334	-14.90	-49.89	.0001	-88.90	-37.83
60.00	.3181	-17.58	-156.06	.0001	-90.58	169.33
65.00	.2348	-20.22	132.87	.0001	-91.75	59.47
70.00	.5466	-12.88	48.33	.0000	-95.32	-71.49
75.00	.5099	-13.48	-74.76	.0001	-93.65	172.33
80.00	.6958	-10.78	-145.52	.0000	-94.78	132.38
85.00	.5687	-12.54	90.78	.0000	-96.94	79.46
90.00	.9939	-7.69	-4.97	.0000	-95.73	53.74
95.00	1.0586	-7.14	-86.88	.0000	-101.14	-40.69
100.00	.8189	-9.37	-178.93	.0000	-96.73	-75.58
105.00	.5928	-12.18	70.63	.0001	-93.08	-135.40
110.00	.3977	-15.64	-56.79	.0001	-92.47	-75.34
115.00	.2773	-18.77	155.92	.0000	-99.47	148.09
120.00	.1990	-21.65	-14.39	.0000	-94.25	-6.10
125.00	.1574	-23.69	152.60	.0001	-89.21	130.22
130.00	.1272	-25.54	-60.51	.0001	-88.89	-47.55
135.00	.0859	-28.95	62.29	.0001	-89.99	121.88
140.00	.0779	-29.80	145.16	.0001	-93.26	-70.31
145.00	.0990	-27.72	-123.60	.0001	-92.57	88.84
150.00	.0756	-30.06	-75.62	.0000	-96.21	-171.22
155.00	.0678	-31.01	-22.03	.0000	-103.01	-47.95
160.00	.0502	-33.63	3.99	.0000	-107.67	-23.78
165.00	.0319	-37.55	35.71	.0000	-116.84	107.66
170.00	.0257	-39.44	80.14	.0000	-103.81	128.89
175.00	.0225	-40.61	106.05	.0000	-97.08	131.34
180.00	1.1964	-6.08	134.28	.0001	-86.08	134.28

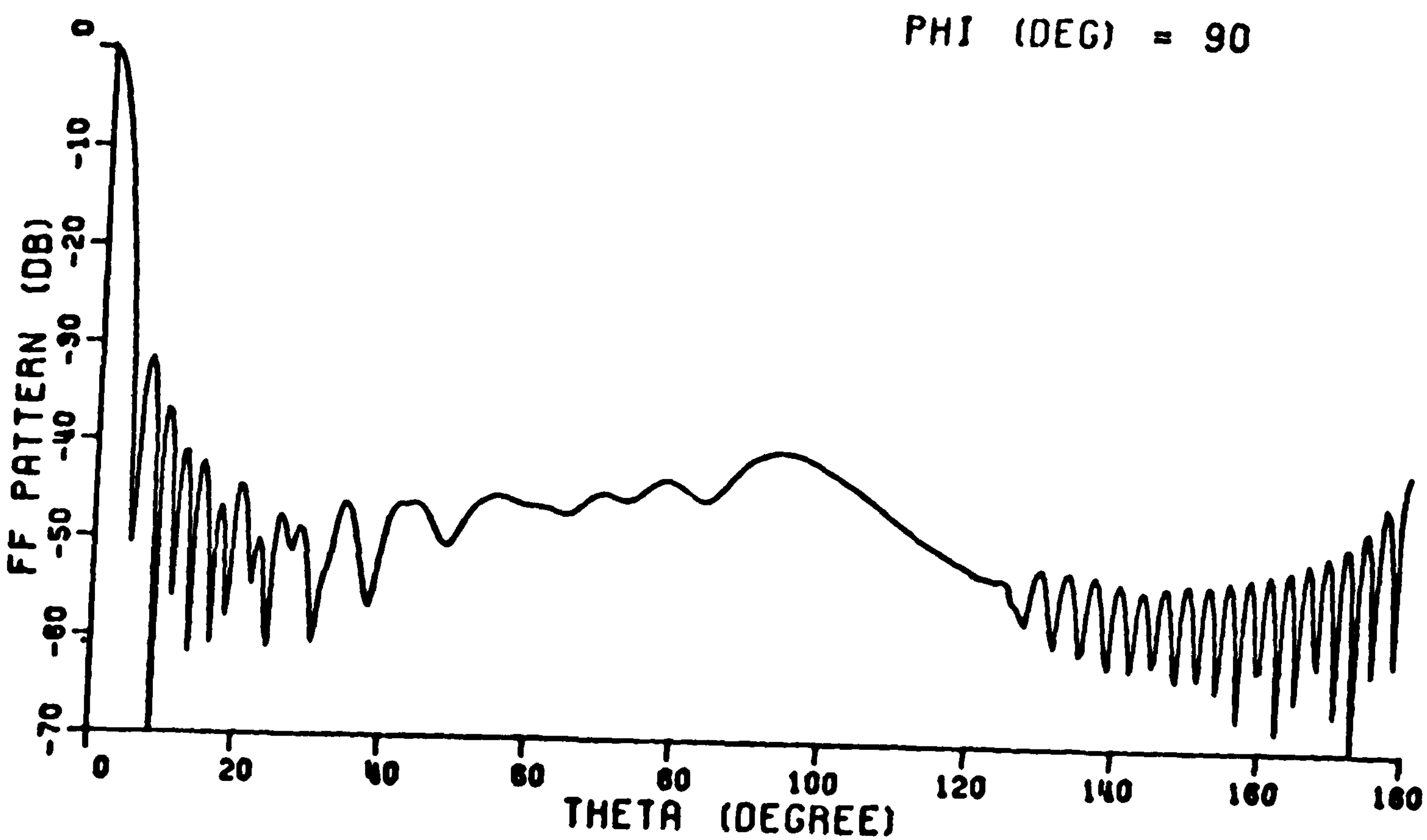
PHI = 90.00

THETA	MAG	DB	PHASE	MAG	DB	PHASE
0.00	138.4469	35.19	33.23	.0000	-195.04	33.23
5.00	.3242	-17.42	9.66	.0000	-188.75	115.90
10.00	2.0594	-1.36	-144.15	.0000	-194.63	105.41
15.00	1.2946	-5.39	-144.36	.0000	-195.52	71.48
20.00	.9228	-8.33	-151.39	.0000	-195.39	27.22
25.00	.4224	-15.12	-156.25	.0000	-96.05	37.68
30.00	.2969	-18.18	77.31	.0000	-96.55	159.34
35.00	.7154	-10.54	52.56	.0000	-102.59	169.36
40.00	.5019	-13.62	12.66	.0000	-96.71	-89.50
45.00	.6690	-11.12	-91.82	.0001	-93.62	94.13
50.00	.4954	-13.73	-138.99	.0000	-94.04	-51.32
55.00	.7608	-10.01	131.08	.0000	-93.82	135.59
60.00	.6776	-11.01	34.97	.0000	-97.49	-50.10
65.00	.6231	-11.74	-45.45	.0000	-126.31	-45.08
70.00	.7866	-9.72	-132.88	.0000	-96.79	-148.80
75.00	.7930	-9.65	122.04	.0000	-97.74	-48.33
80.00	.8997	-8.55	32.58	.0000	-100.12	25.55
85.00	.7798	-9.79	-86.20	.0000	-99.55	77.68
90.00	1.2394	-5.77	172.47	.0000	-98.49	98.72
95.00	1.3330	-5.14	90.23	.0000	-98.27	107.97
100.00	1.0979	-6.82	-4.12	.0000	-94.57	80.75
105.00	.8391	-9.16	-114.47	.0001	-91.17	25.55
110.00	.5940	-12.16	118.82	.0001	-90.09	129.91
115.00	.4450	-14.66	-27.70	.0000	-93.93	-21.69
120.00	.3406	-16.99	162.38	.0000	-101.58	170.90
125.00	.3044	-17.96	-29.86	.0000	-100.35	85.91
130.00	.3306	-17.25	126.49	.0000	-100.47	-40.19
135.00	.1318	-25.23	-105.51	.0000	-95.26	138.81
140.00	.2845	-18.55	-40.14	.0001	-92.80	-57.40
145.00	.1189	-26.13	77.27	.0000	-94.25	77.91
150.00	.3132	-17.72	130.20	.0000	-96.46	158.53
155.00	.2660	-19.13	142.28	.0000	-105.67	167.09
160.00	.1160	-26.35	161.49	.0000	-111.05	-175.55
165.00	.0795	-29.63	-84.14	.0000	-116.72	-144.26
170.00	.2240	-20.63	-55.85	.0000	-117.76	-87.33
175.00	.4486	-14.60	-49.44	.0000	-116.27	-53.76
180.00	1.1964	-6.08	-45.72	.0001	-86.08	-45.72



(a)

Figure 9. Far field patterns of circular reflector example computed by general reflector code.



(b)

Figure 9. (Continued)

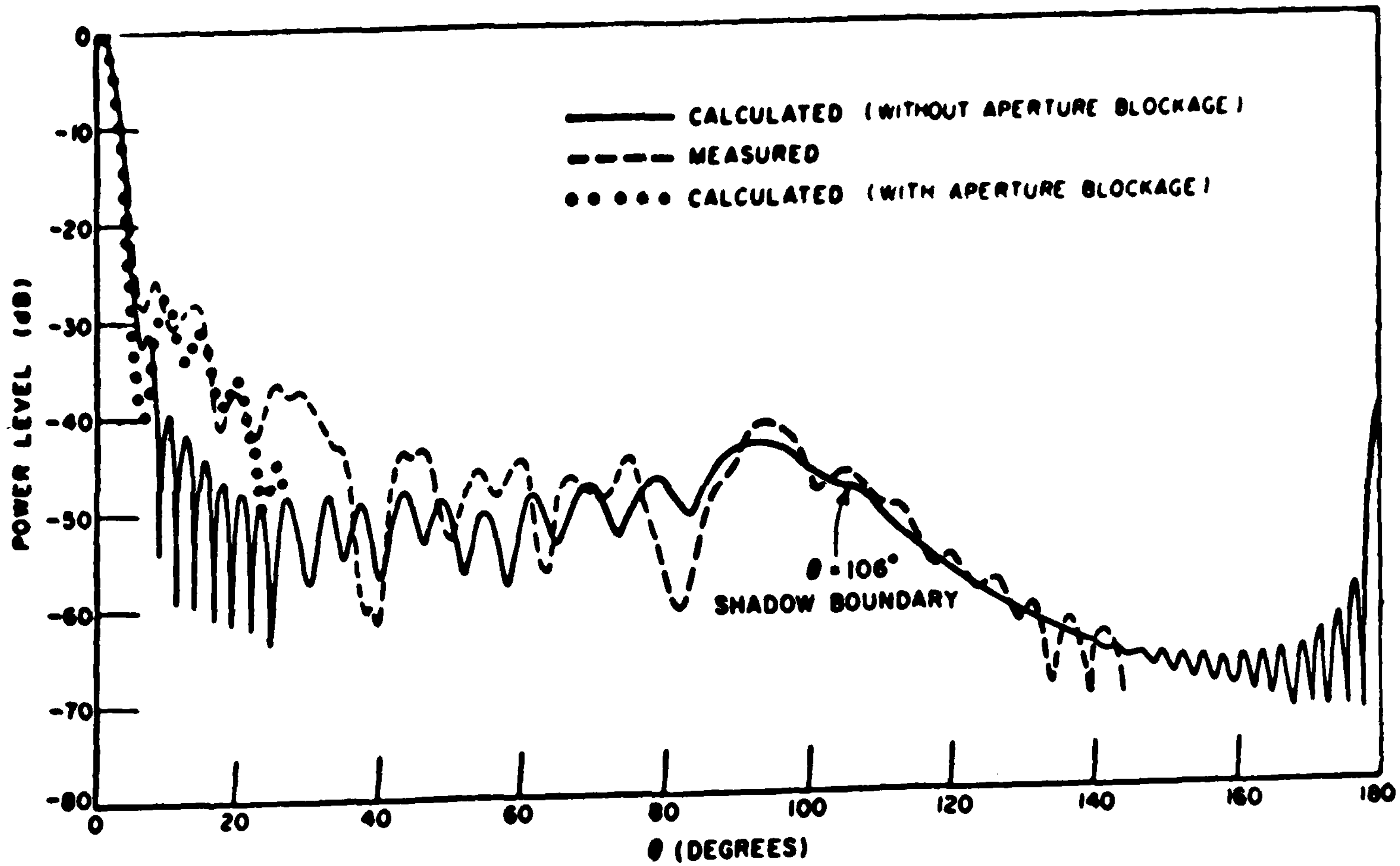


Figure 10. H-plane pattern of a parabolic reflector with a flanged waveguide feed. Computed in Reference [3].

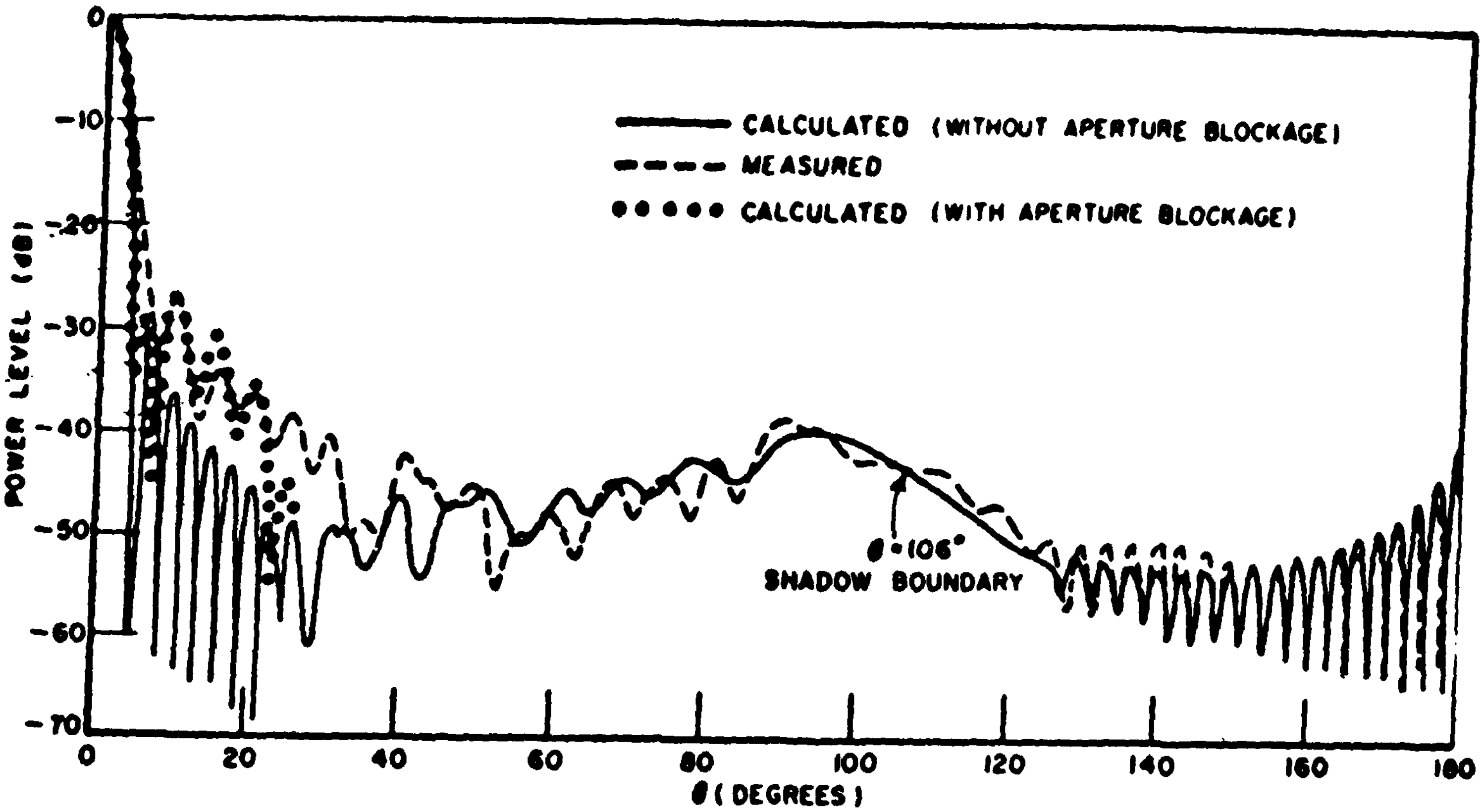


Figure 11. E-plane pattern of a parabolic reflector with a flanged waveguide feed. Computed in Reference [3].

Example 2. This example illustrates the flexibility of the general reflector code for treating various rim geometries. The antenna used in this example has a 19λ x 11λ rectangular aperture with chopped corners and a focal distance F=10λ as shown in Figure 12. The feed patterns for this reflector are shown in Figure 13. The input data for this case are given below:

```
DG:
3,10.,1.,0.5,0.
6
-9.5,-4.,-6.,-5.5,6.,-5.5,9.5,-4.,
9.5,3.,7.,5.5,-7.,5.5,-9.5,3.
TO:
F,F,F,F,F
T,T
T,T,T
0.,0.
FD:
F,F,F,1,90.
2,0.,90.
1,6.,0.,100.,6.,0.,90.
FQ:
1,11.81
PZ:
3
0.,45.,90.
0.,180.,5.
XQ:
```

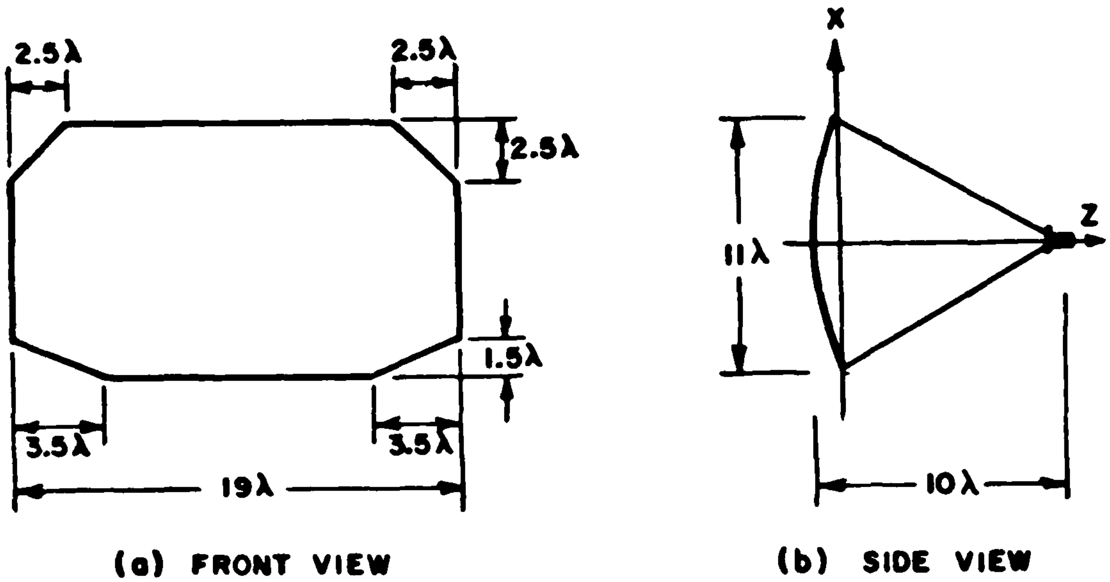
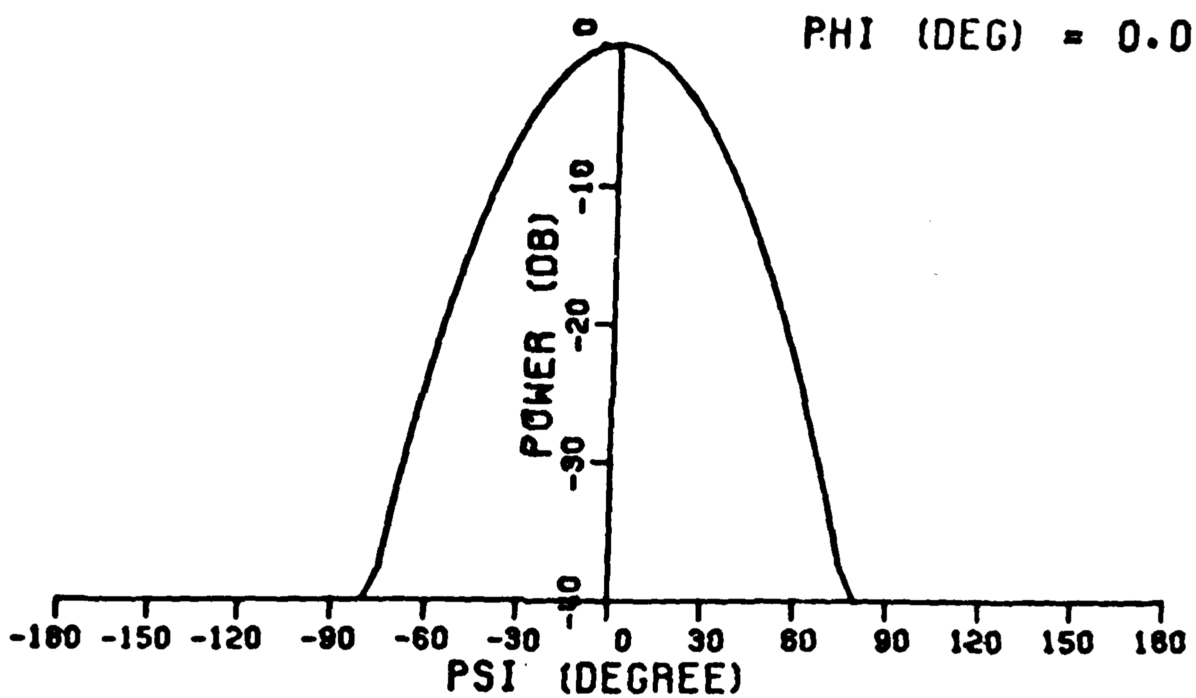
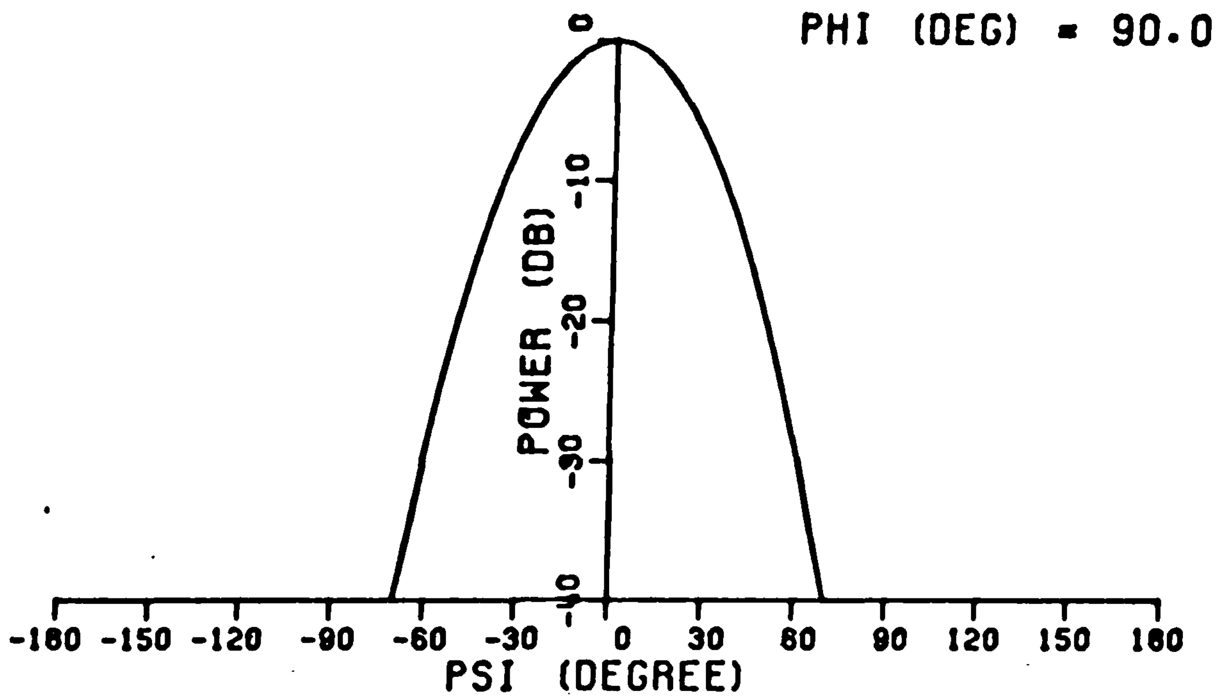


Figure 12. Rectangular reflector with chopped corners.



(a)

Figure 13. Input feed patterns for rectangular reflector geometries.



(b)

Figure 13. (Continued)

The output data for Example 2 are as given below. The far field patterns computed by the general reflector code are shown in Figures 15a to c for this example of a reflector with chopped corners.

DEFAULT DATA

CIRCULAR REFLECTOR WITH APERTURE DIAMETER = .61

FOCAL DISTANCE= .203 GRIDX= .015 GRIDY = .015

FEED PATTERN SYMMETRY GIVEN BY: ISYM= 1

LINEARLY POLARIZED FEED
POLARIZED ANGLE = 90.00

FEED AXIS TILT ANGLE = 0.00

NPW = 1

N	PHIN(N)	PSIO(N)	AEX(N)	CAN(N)
1	0.0	120.0	5.0	.09
2	90.0	140.0	6.0	.10

DG:

COORDINATES OF RIM POINTS IN METERS

RIM POINT	X	Y
1	-.24	-.10
2	-.15	-.14
3	.15	-.14
4	.24	-.10
5	.24	.08
6	.13	.14
7	-.13	.14
8	-.24	.08

FOCAL DISTANCE= .254 GRIDX= .025 GRIDY = .013

```
TO:

    LDEBUG=   F      LTEST=    F       LOUT=   F      LWFD =   F

    LSLOPE=   T      LCORNR=    T

    LAI =   T        LFEED =   T       LGTD =   T

    THETAX = 0.00    ZX = 0.00
```

```
FD:

    FEED PATTERN SYMMETRY GIVEN BY: ISYM= 1

    LINEARLY POLARIZED FEED
      POLARIZED ANGLE =  90.00

      FEED AXIS TILT ANGLE =     0.00

      NPW = 1

            N          PHIN(N)       PSIO(N)         AEX(N)        CAN(N)
            1            0.0          100.0            6.0           0.00
            2           90.0           90.0            6.0           0.00
```

```
FQ:

FOR THIS GEOMETRY, THERE WILL BE    1 FREQUENCIES CONSIDERED AS FOLLOWS:
11.81,
```

```
PHI:

USING THE PRESENT GEOMETRY, THERE WILL BE   3 PHI PATTERN CUTS COMPUTED

SINCE INP IS POSITIVE THE FOLLOWING PHI CUTS WILL BE COMPUTED:
  0.0,  45.0,  90.0,

FOR EACH PHI CUT THE PATTERN WILL BE COMPUTED EACH   5.0 DEGREES IN THETA
```

```
XQ:

     PRAD =  .568E  0

     FREQUENCY =     11.810 GHZ

     COORDINATES OF RIM POINTS (WAVELENGTHS)
                 RIM POINT         X            Y
                     1           -9.50        -4.00
                     2           -6.00        -5.50
                     3            6.00        -5.50
                     4            9.50        -4.00
                     5            9.50         3.00
                     6            7.00         5.50
                     7           -7.00         5.50
                     8           -9.50         3.00

       FOCAL DISTANCE =  10.00 WAVELENGTHS

       REFDB =    -6.549
```

PHI = 0.00

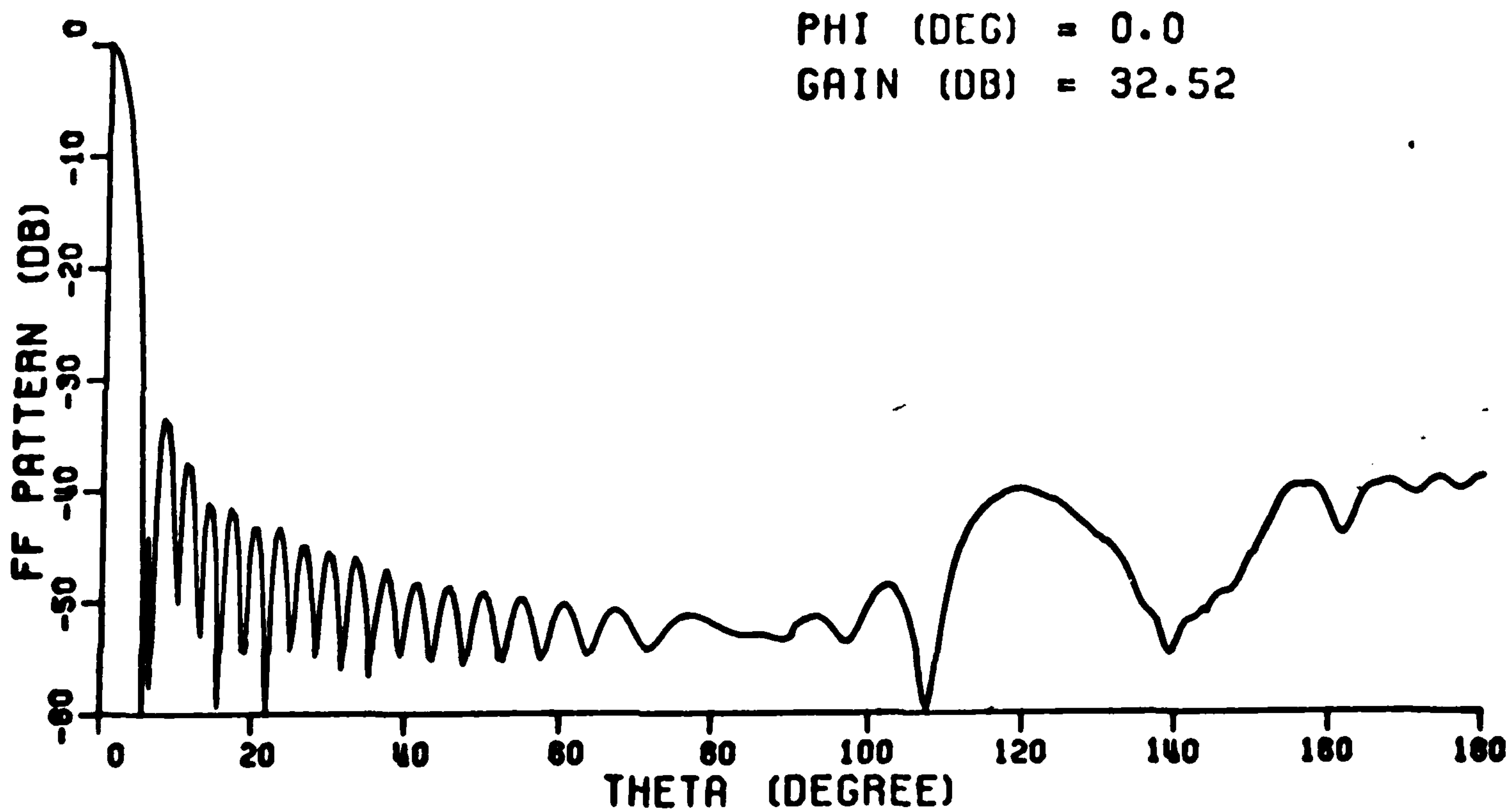
THETA	MAG	DB	PHASE	MAG	DB	PHASE
0.00	89.8172	32.52	34.14	.0000	-142.20	34.14
5.00	2.2409	.46	34.14	.0000	-174.30	33.59
10.00	.2816	-17.56	-145.86	.0000	-192.45	-147.30
15.00	.4797	-12.93	34.14	.0000	-137.16	34.66
20.00	.6118	-10.82	34.15	.0000	-185.21	33.00
25.00	.1714	-21.87	-59.39	.0219	-39.75	82.25
30.00	.4766	-12.99	-124.91	.0090	-47.47	-86.08
35.00	.2606	-18.23	99.56	.0099	-46.60	133.91
40.00	.2333	-19.19	33.70	.0095	-46.97	-110.52
45.00	.3191	-16.47	-117.01	.0086	-47.90	83.18
50.00	.3112	-16.69	81.30	.0063	-50.63	-97.18
55.00	.2920	-17.24	-89.60	.0054	-51.91	82.19
60.00	.2738	-17.80	87.06	.0049	-52.82	-119.50
65.00	.2050	-20.32	-118.67	.0045	-53.45	14.04
70.00	.1980	-20.62	-19.81	.0046	-53.22	120.80
75.00	.2322	-19.23	97.16	.0048	-53.01	-141.32
80.00	.2260	-19.47	156.29	.0049	-52.71	-78.63
85.00	.2005	-20.51	-152.08	.0050	-52.53	-37.77
90.00	.1959	-20.71	-124.02	.0053	-52.04	-24.16
95.00	.2202	-19.69	-137.28	.0053	-52.11	-46.04
100.00	.2778	-17.67	-146.30	.0060	-51.00	-81.00
105.00	.2370	-19.06	117.16	.0066	-50.18	-137.07
110.00	.3061	-16.83	114.90	.0080	-48.43	142.61
115.00	.7549	-8.99	-36.50	.0089	-47.55	45.10
120.00	.8980	-7.48	149.72	.0111	-45.65	-94.81
125.00	.7640	-8.89	-33.96	.0123	-44.72	117.12
130.00	.5441	-11.34	135.40	.0121	-44.92	-78.24
135.00	.3033	-16.91	-73.92	.0152	-42.89	60.24
140.00	.1839	-21.26	29.78	.0170	-41.92	-118.32
145.00	.2921	-17.24	-167.86	.0165	-42.19	63.41
150.00	.4659	-13.18	68.10	.0145	-43.33	-172.48
155.00	.9251	-7.23	-66.24	.0139	-43.69	-74.26
160.00	.6983	-9.67	172.38	.0178	-41.52	11.12
165.00	.9070	-7.40	123.26	.0323	-36.37	120.24
170.00	.8916	-7.55	56.96	.0378	-34.99	-93.13
175.00	.9940	-6.60	21.77	.0181	-41.41	74.62
180.00	1.0229	-6.35	11.05	.0001	-86.35	11.05

PHI = 45.00

THETA	MAG	DB	PHASE	MAG	DB	PHASE
0.00	89.6156	32.50	34.14	.0000	-142.14	28.18
5.00	10.9031	14.20	34.60	.0208	-40.19	34.60
10.00	.6307	-10.55	29.42	.0048	-52.87	29.42
15.00	.5014	-12.55	21.91	.0087	-47.77	21.91
20.00	.1174	-25.16	-119.37	.0036	-55.31	-119.38
25.00	.1708	-21.90	-142.58	.0311	-36.69	-121.57
30.00	.1443	-23.36	89.87	.0193	-40.82	135.52
35.00	.0757	-28.97	4.18	.0405	-34.41	15.22
40.00	.0895	-27.51	-106.60	.0311	-36.69	-136.62
45.00	.0653	-30.25	31.58	.0513	-32.34	85.36
50.00	.1349	-23.95	-68.22	.0273	-37.83	-81.70
55.00	.0515	-32.32	60.34	.0561	-31.56	120.94
60.00	.0761	-28.92	-77.51	.0402	-34.47	-104.26
65.00	.0854	-27.92	52.93	.0320	-36.44	57.63
70.00	.0522	-32.20	146.68	.0539	-31.92	-172.15
75.00	.0326	-36.27	-83.30	.0641	-30.42	-90.09
80.00	.0378	-35.01	-5.93	.0638	-30.45	-21.78
85.00	.0370	-35.19	42.51	.0615	-30.78	28.15
90.00	.0347	-35.74	65.34	.0670	-30.02	53.80
95.00	.0319	-36.47	57.95	.0784	-28.66	88.03
100.00	.0324	-36.34	46.15	.0230	-39.32	9.84
105.00	.0281	-37.59	14.97	.1420	-23.50	17.47
110.00	.0174	-41.72	-59.22	.1343	-23.99	-132.86
115.00	.0221	-39.65	-149.54	.3415	-15.88	-62.44
120.00	.0242	-38.88	117.52	.6836	-9.85	116.30
125.00	.0124	-44.69	-27.10	.9549	-6.95	-59.13
130.00	.0165	-42.18	162.70	1.0416	-6.20	119.50
135.00	.0089	-47.52	-25.45	1.0440	-6.18	-52.92
140.00	.0199	-40.55	-120.38	1.0635	-6.01	131.37
145.00	.0200	-40.51	-141.36	.6276	-10.60	-41.98
150.00	.0364	-35.33	161.15	1.1225	-5.55	168.08
155.00	.0181	-41.39	137.30	.5242	-12.16	-18.75
160.00	.0192	-40.87	43.88	.6499	-10.29	-130.94
165.00	.0247	-38.71	94.41	1.0117	-6.45	52.71
170.00	.0151	-42.99	100.20	.3424	-15.36	-144.13
175.00	.0035	-55.78	-73.00	.5910	-11.12	-171.72
180.00	.0001	-86.35	-163.95	1.0229	-6.35	11.05

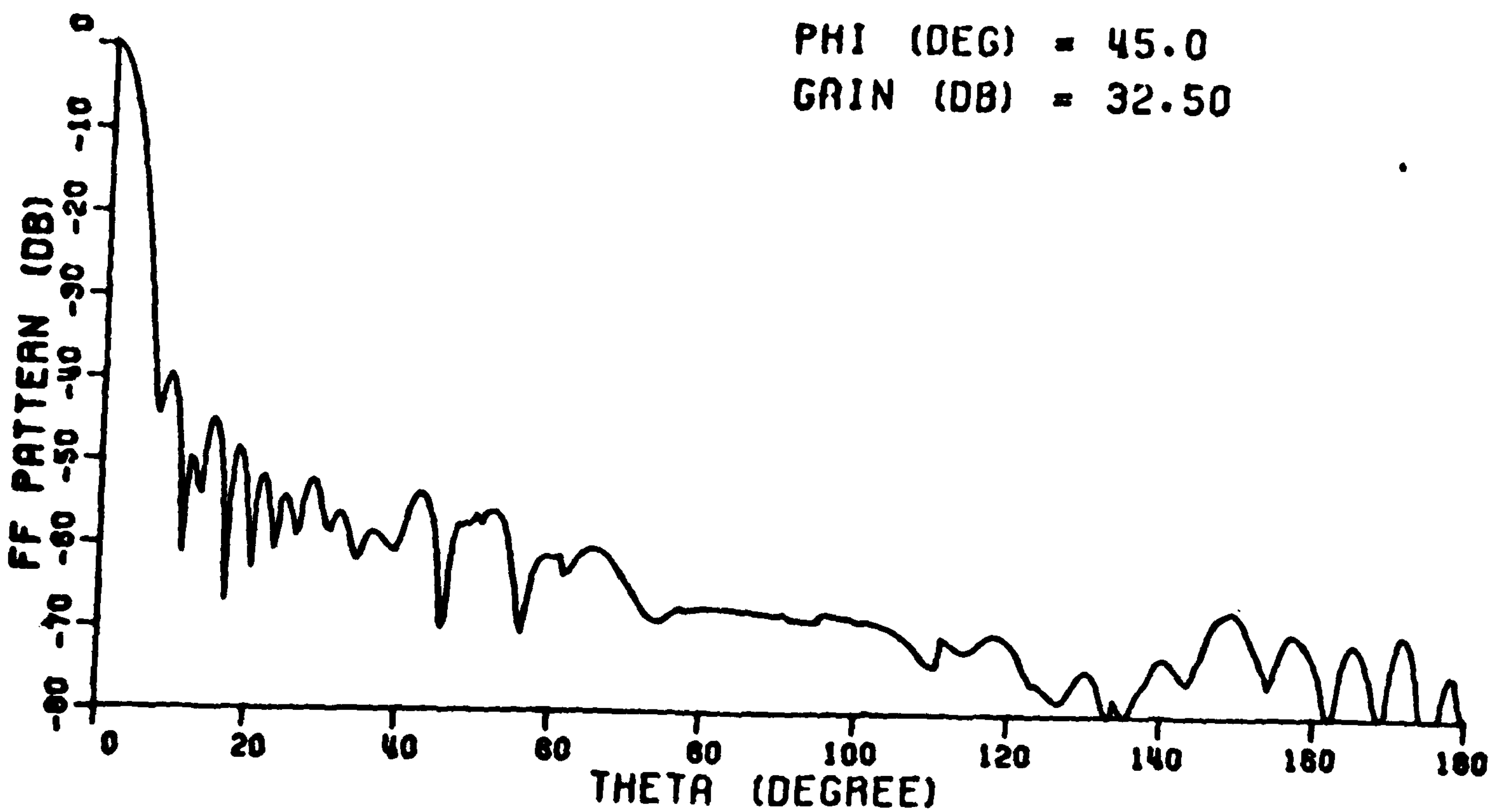
PHI = 90.00

THETA	MAG	DB	PHASE	MAG	DB	PHASE
0.00	89.7915	32.52	34.14	.0000	-198.87	34.14
5.00	19.7039	19.34	33.83	.0000	-188.81	125.43
10.00	4.7631	7.01	-146.88	.0000	-199.40	147.70
15.00	3.4873	4.30	35.18	.0000	-201.17	137.20
20.00	2.8223	2.46	-142.03	.0000	-206.93	152.75
25.00	2.5944	1.73	37.91	.0000	-205.86	148.54
30.00	2.1123	-.05	-144.56	.0000	-206.14	178.93
35.00	1.3415	-4.00	32.17	.0000	-210.71	-157.06
40.00	.1678	-22.05	-165.27	.0000	-207.52	-175.56
45.00	1.1547	-5.30	11.47	.0002	-80.73	116.72
50.00	1.1809	-5.10	-95.38	.0002	-81.37	-18.99
55.00	.6686	-10.05	-149.01	.0001	-87.22	-62.51
60.00	.8716	-7.74	160.28	.0002	-82.45	-143.34
65.00	.5957	-11.05	128.76	.0001	-84.05	-169.19
70.00	.5862	-11.19	108.52	.0001	-83.49	154.33
75.00	.4749	-13.02	110.57	.0002	-82.56	140.74
80.00	.4083	-14.33	125.31	.0002	-81.38	137.18
85.00	.3570	-15.50	166.90	.0002	-80.56	147.10
90.00	.3288	-16.21	-128.22	.0002	-80.77	162.94
95.00	.1255	-24.58	-80.69	.0000	-108.95	-54.12
100.00	.1423	-23.48	-42.76	.0000	-103.04	-26.97
105.00	.2963	-17.11	-27.32	.0002	-78.76	78.83
110.00	.6684	-10.05	23.47	.0003	-78.00	139.73
115.00	.3952	-14.61	151.48	.0003	-76.59	-141.64
120.00	1.0220	-6.36	-71.42	.0003	-76.13	-61.07
125.00	.3900	-14.73	96.44	.0002	-80.30	37.19
130.00	1.3944	-3.66	-110.59	.0002	-80.21	163.05
135.00	2.3312	.80	112.31	.0001	-90.98	-127.18
140.00	2.3463	.86	-22.51	.0001	-83.12	56.21
145.00	1.8838	-1.05	-155.96	.0002	-81.50	-44.32
150.00	1.4324	-3.43	69.30	.0002	-81.17	59.60
155.00	1.2467	-4.63	-69.18	.0001	-84.31	-84.96
160.00	1.1389	-5.42	143.03	.0001	-86.98	144.28
165.00	1.1183	-5.58	-14.06	.0001	-85.73	-2.69
170.00	1.0234	-6.35	-175.52	.0001	-85.63	-163.64
175.00	.8747	-7.71	6.14	.0001	-87.53	13.62
180.00	1.0229	-6.35	-168.95	.0001	-86.35	-168.95



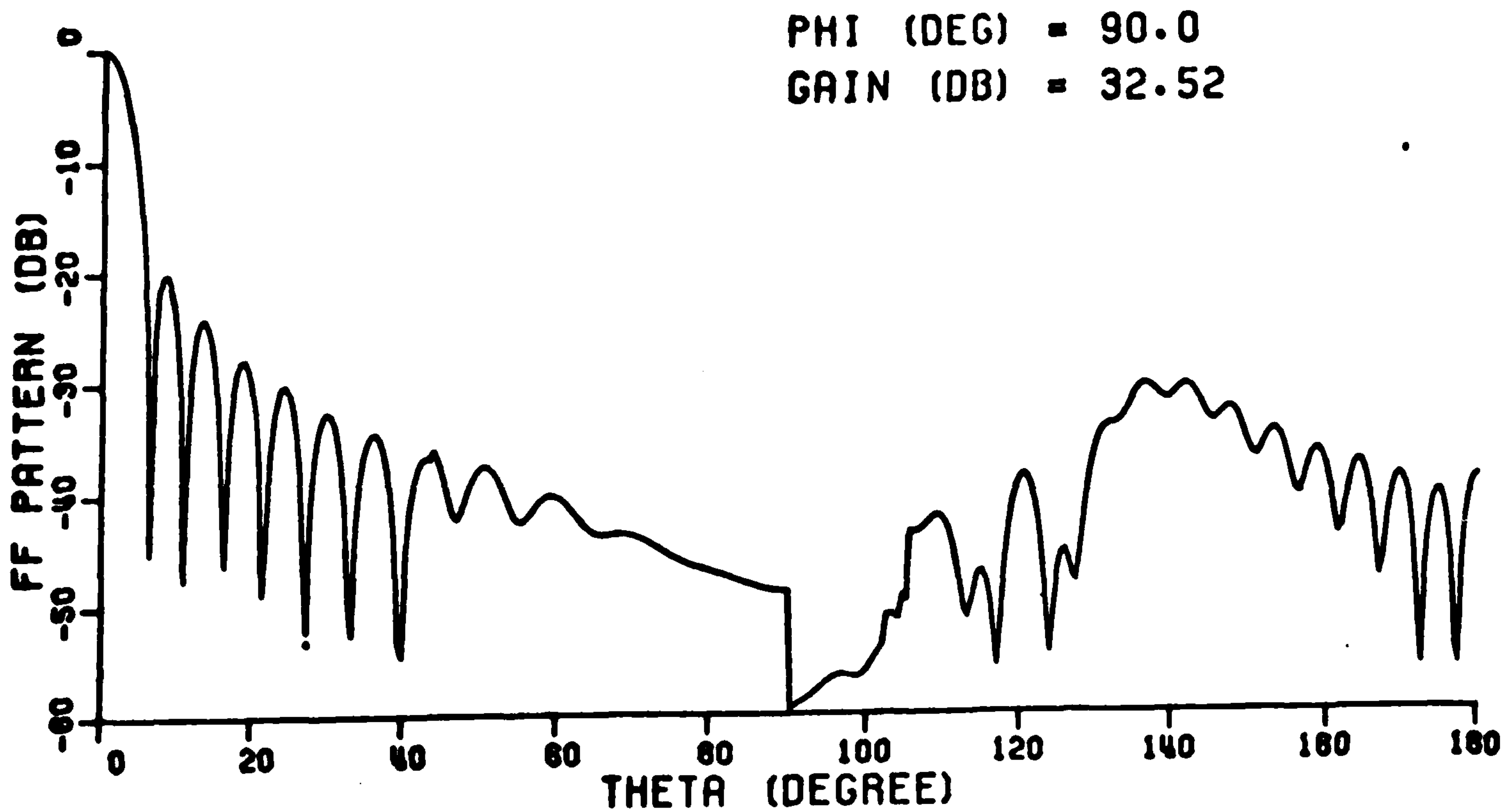
(a)

Figure 15. Far field patterns of rectangular reflector antenna with chopped corners.



(b)

Figure 15. (Continued)



(c)

Figure 15. (Continued)

Example 3 is an off-set fed reflector system with a corrugated horn feed designed at NRL [4]. The geometry of the antenna is shown in Figure 16. The input feed pattern used in the code was read from the envelope of the measured horn pattern [4] shown in Figure 17. The E-plane far field pattern calculated by both AI and GTD is shown in Figure 18. This example shows the use of the TL: Command for a feed axis tilt. The input data are given below:

```
DG:
1,0.3281,0.01,0.01,0.352
TO:
F,F,F,F,F
T,T
T,F,F
0.,0.
TL:
90.,0.6566
FD:
T,F,T,1,90.
2,0.,90.
12
0.,-0.03
2.,-0.1
5.,-1.2
10.,-6.12
15.,-17.6
20.,-30.1
25.,-39.6
30.,-46.7
40.,-54.
50.,-59.4
90.,-75.5
180.,-95.
0.,-0.03
2.,-0.1
5.,-1.2
10.,-6.12
15.,-17.6
20.,-30.1
25.,-39.6
30.,-46.7
40.,-54.
50.,-59.4
90.,-75.5
180.,-95.
FO:
1.,37.
NF:
F,F
FZ:
1
90.
0.,90.,2.
PP:
F,0
XQ:
```

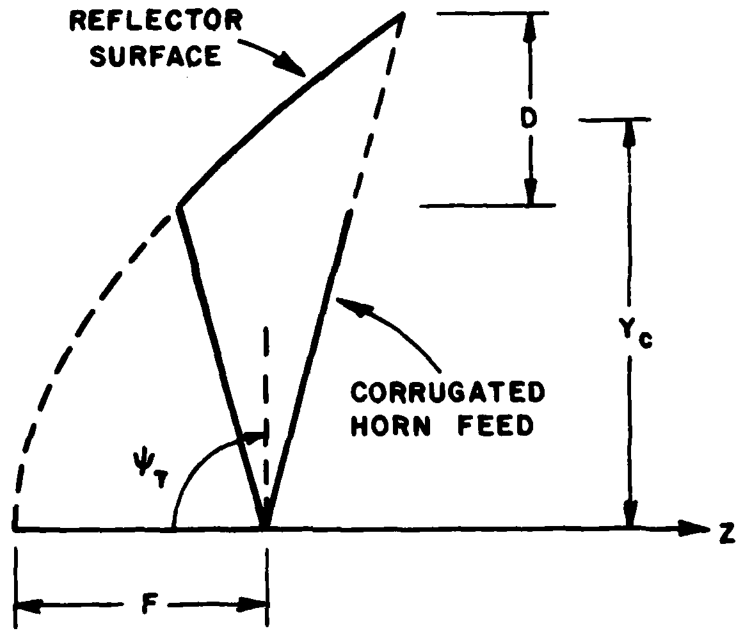


Figure 16. Geometry of an off-set fed reflector antenna with
$D = 35.2$ cm
$F = 32.83$ cm
$Y_C = 65.66$ cm
$\psi_T = 90^\circ$.

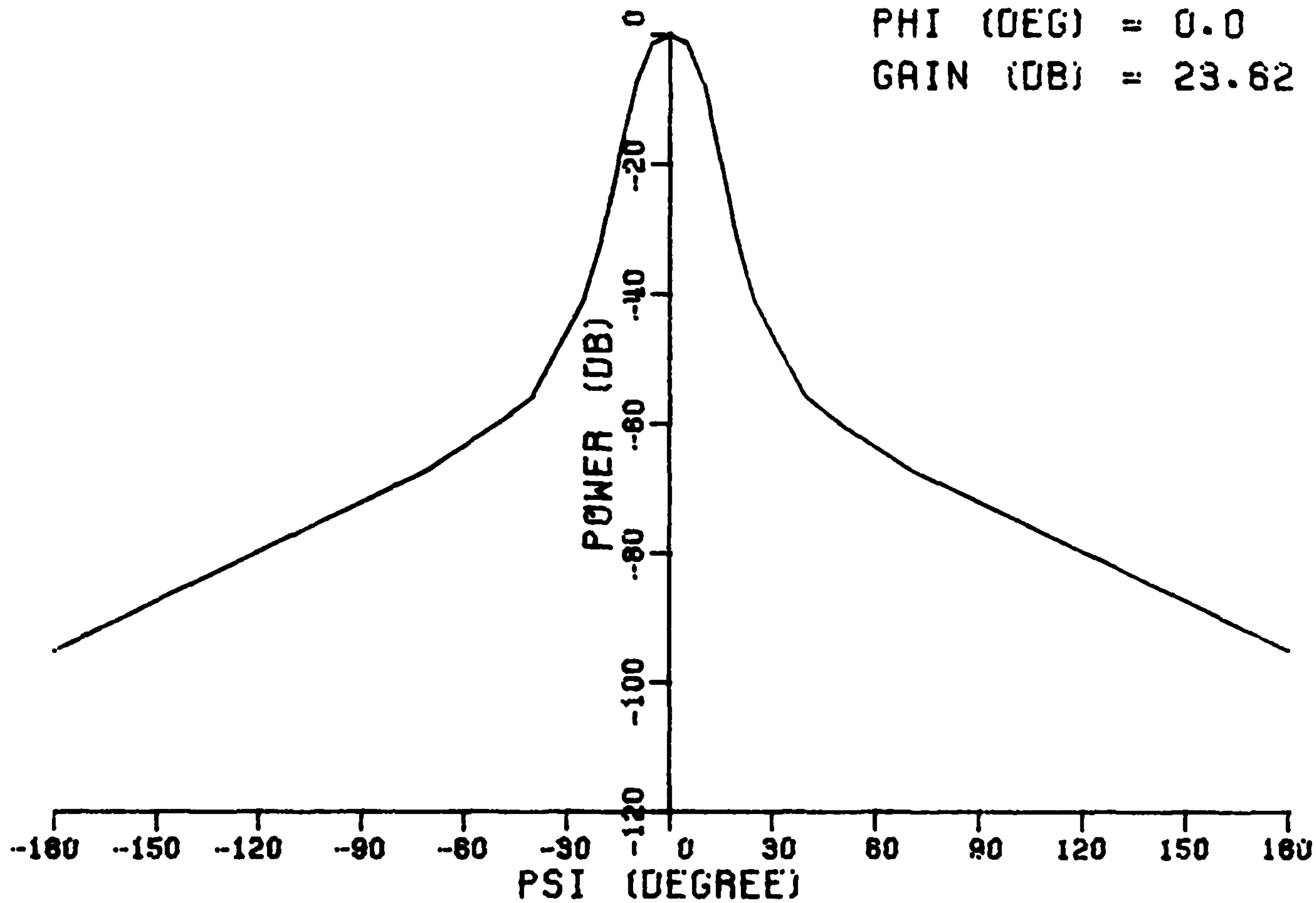


Figure 17. Input feed pattern for offset circular reflector of Figure 16.

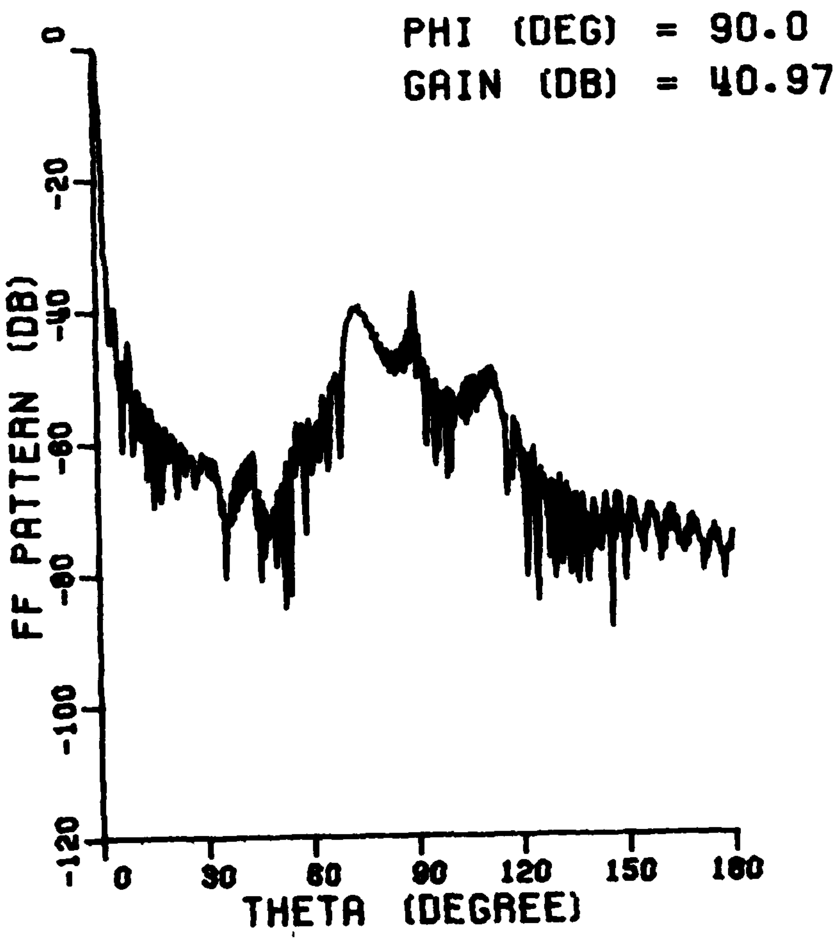


Figure 18. Longitudinal plane ($\phi=90^0$) pattern for offset circular reflector of Figure 16 at 37 GHz.

The output data for Example 3 as calculated by AI are given below:

```
*****************************************************************************
*                                                                           *
*                   DEFAULT DATA                                            *
*                                                                           *
*                                                                           *
*  LINEAR DIMENSION INPUTS ARE IN INCHES                                    *
*                                                                           *
*     CIRCULAR REFLECTOR WITH APERTURE DIAMETER =     24.00                 *
*                                                                           *
*                                                                           *
*       FOCAL DISTANCE=      8.00 GRIDX=    .600      GRIDY =    .600       *
*                                                                           *
*     FEED PATTERN SYMMETRY GIVEN BY:ISYM= 1                                *
*                                                                           *
*     LINEARLY POLARIZED FEED                                               *
*                                                                           *
*       POLARIZED ANGLE =  90.00                                            *
*                                                                           *
*       FEED DATA INPUT IN DB.                                              *
*                                                                           *
*                                                                           *
*         NPW = 1                                                           *
*             N          PHIN(N)      PSIO(N)         AEX(N)       CAN(N)   *
*             1           0.0          120.0           5.0          .09     *
*             2          90.0          140.0           6.0          .10     *
*                                                                           *
*                                                                           *
*****************************************************************************


*****************************************************************************
*                                                                           *
*  DG:                                                                      *
*                                                                           *
*                                                                           *
*  LINEAR DIMENSION INPUTS ARE IN METERS                                    *
*                                                                           *
*     CIRCULAR REFLECTOR WITH APERTURE DIAMETER =      .35                  *
*                                                                           *
*                                                                           *
*       FOCAL DISTANCE=       .33 GRIDX=    .010      GRIDY =    .010       *
*                                                                           *
*                                                                           *
*****************************************************************************
```

```
************************************************************************
*                                                                      *
*  TC:                                                                 *
*                                                                      *
*                                                                      *
*     LDEBUG=  F     LTEST=  F     LWYSUM= F     LOUT = F     LWFD = F *
*                                                                      *
*     LSLOPE=  T     LCORNR=  T                                        *
*                                                                      *
*     LAI = T        LFEED = F     LGTD = F                            *
*                                                                      *
*     THETAX = Ø.ØØ     ZX =     Ø.ØØØ                                 *
*                                                                      *
*                                                                      *
************************************************************************
```

```
************************************************************************
*                                                                      *
*  TL:                                                                 *
*                                                                      *
*                                                                      *
*       FEED AXIS TILT ANGLE =   9Ø.ØØ                                 *
*                                                                      *
*       APERTURE CENTER AT (Ø.,    .657)                               *
*                                                                      *
*                                                                      *
*                                                                      *
************************************************************************
```

```
FEED

    FEED PATTERN SYMMETRY GIVEN BY:ISYM= 1

    LINEARLY POLARIZED FEED

      POLARIZED ANGLE =  90.00

      FEED DATA INPUT IN DB.


      MAXIMUM NUMBER OF FEED POINTS=12

    Y-ORIENTED DIPOLE FEED

    PHIN(1) =   0.0

      PIECEWISE LINEAR FEED INPUT
              PSI             F            F(DB)

             0.00          .9966           -.03
             2.00          .9886           -.10
             5.00          .8710          -1.20
            10.00          .4943          -6.12
            15.00          .1318         -17.60
            20.00          .0313         -30.10
            25.00          .0105         -39.60
            30.00          .0046         -46.70
            40.00          .0020         -54.00
            50.00          .0011         -59.40
            90.00          .0002         -75.50
           180.00          .0000         -95.00
    PHIN(2) =  90.0

      PIECEWISE LINEAR FEED INPUT
              PSI             F            F(DB)

             0.00          .9966           -.03
             2.00          .9886           -.10
             5.00          .8710          -1.20
            10.00          .4943          -6.12
            15.00          .1318         -17.60
            20.00          .0313         -30.10
            25.00          .0105         -39.60
            30.00          .0046         -46.70
            40.00          .0020         -54.00
            50.00          .0011         -59.40
            90.00          .0002         -75.50
           180.00          .0000         -95.00
```

```
*************************************************************************
*                                                                       *
*  FG:                                                                  *
*                                                                       *
*                                                                       *
* FOR THIS GEOMETRY,THERE WILL BE    1 FREQUENCIES CONSIDERED AS FOLLOWS:  *
* 37.00,
*                                                                       *
*                                                                       *
*************************************************************************


*************************************************************************
*                                                                       *
*  NF:                                                                  *
*                                                                       *
*                                                                       *
*                                                                       *
*  FAR FIELD PATTERN WILL BE CALCULATED                                 *
*                                                                       *
*                                                                       *
*************************************************************************


*************************************************************************
*                                                                       *
*  PZ:                                                                  *
*                                                                       *
*                                                                       *
* USING THE PRESENT GEOMETRY,THERE WILL BE    1 PATTERN CUTS COMPUTED   *
*                                                                       *
*                                                                       *
* SINCE IP2 IS POSITIVE THE FOLLOWING CUTS WILL BE COMPUTED:            *
*  90.0,
*                                                                       *
*     AP3I =    0.00      AP3F =   90.00                                *
*                                                                       *
*  FOR EACH CUT THE PATTERN WILL BE COMPUTED EACH    2.0 DEGREES THETA OR  *
*                                                                       *
*  INPUT UNIT IN RHO                                                    *
*                                                                       *
*                                                                       *
*                                                                       *
*************************************************************************
```

XO:

PRAD = .617E -1

FREQUENCY = 37.000 GHZ

WAVELENGTH = .008108 METERS
* THE FOLLOWING DIMENSION UNITS ARE IN WAVELENGTHS *

NUMBER OF RIM SEGMENTS= 32

APERTURE DIAMETER = 43.41 WAVELENGTHS

APERTURE CENTER AT (0., 80.98)

COORDINATES OF RIM POINTS (WAVELENGTHS)

RIM POINT	X	Y
1	21.65	83.11
2	20.82	87.30
3	19.19	91.24
4	16.82	94.78
5	13.80	97.80
6	10.26	100.17
7	6.32	101.80
8	2.13	102.64
9	-2.13	102.64
10	-6.32	101.80
11	-10.26	100.17
12	-13.80	97.80
13	-16.82	94.78
14	-19.19	91.24
15	-20.82	87.30
16	-21.65	83.11
17	-21.65	78.85
18	-20.82	74.66
19	-19.19	70.72
20	-16.82	67.18
21	-13.80	64.16
22	-10.26	61.79
23	-6.32	60.16
24	-2.13	59.33
25	2.13	59.33
26	6.32	60.16
27	10.26	61.79
28	13.80	64.16
29	16.82	67.18
30	19.19	70.72
31	20.82	74.66
32	21.65	78.85

FOCAL DISTANCE = 40.47

GRIDX = 1.23 GRIDY = 1.23

REFDB = -9.054

PHI = 90.00

THETA	PRINCIPAL POL MAG	PRINCIPAL POL DB	PRINCIPAL POL PHASE	CROSS POL MAG	CROSS POL DB	CROSS POL PHASE
0.0	.327E 3	41.25	63.59	.258E -5	-120.83	63.60
2.0	.251E 2	18.94	-18.10	.807E -6	-130.92	-17.53
4.0	.409E 1	3.19	-32.09	.952E -7	-149.49	-74.63
6.0	.143E 1	-5.93	173.57	.808E -7	-150.91	-125.12
8.0	.115E 1	-7.86	-22.71	.808E -7	-150.90	112.05
10.0	.575E 0	-13.87	-101.34	.108E -6	-148.40	-29.46
12.0	.574E 0	-13.88	28.62	.562E -7	-154.05	143.06
14.0	.360E 0	-17.92	-118.40	.297E -7	-159.60	-143.27
16.0	.504E 0	-15.01	1.03	.345E -8	-178.31	-151.35
18.0	.139E 0	-26.17	-159.15	.459E -7	-155.81	-98.32
20.0	.341E 0	-18.39	-45.03	.304E -7	-159.39	64.54
22.0	.819E -1	-30.79	97.76	.449E -7	-156.00	-165.50
24.0	.265E 0	-20.57	-143.86	.570E -7	-153.93	-78.68
26.0	.158E 0	-25.10	-99.45	.363E -7	-157.85	-9.81
28.0	.106E 0	-28.52	38.78	.155E -7	-165.26	77.16
30.0	.217E 0	-22.32	52.74	.191E -7	-163.41	174.93
32.0	.146E 0	-25.77	46.01	.157E -8	-185.13	81.57
34.0	.560E -1	-34.09	88.85	.681E -8	-172.39	-2.56
36.0	.962E -1	-29.39	92.51	.377E -8	-177.53	-55.79
38.0	.139E 0	-26.21	7.28	.656E -8	-172.72	-51.18
40.0	.121E 0	-27.38	-92.35	.708E -8	-172.05	-48.78
42.0	.874E -1	-30.22	167.08	.348E -8	-178.22	-56.92
44.0	.664E -1	-32.61	50.72	.188E -8	-183.56	-69.15
46.0	.467E -1	-35.66	-93.59	.142E -8	-186.01	-90.99
48.0	.583E -1	-33.74	85.22	.764E -9	-191.39	-81.38
50.0	.609E -1	-33.36	-131.31	.110E -8	-188.19	-148.17
52.0	.389E -1	-37.25	139.67	.119E -8	-187.54	138.98
54.0	.597E -1	-33.54	-28.62	.147E -9	-205.68	-34.16
56.0	.973E -1	-29.30	-79.57	.679E -9	-192.42	-134.25
58.0	.106E 0	-28.54	-24.79	.126E -8	-187.01	54.49
60.0	.783E -1	-31.17	-72.09	.508E -9	-194.93	-168.42
62.0	.476E -1	-35.51	-160.76	.541E -9	-194.39	11.05
64.0	.486E -1	-35.32	16.53	.872E -9	-190.25	104.23
66.0	.815E -1	-30.83	-127.30	.775E -9	-191.27	174.76
68.0	.404E -1	-36.93	46.86	.936E -9	-189.63	-145.26
70.0	.862E -1	-30.34	98.25	.122E -8	-187.31	-164.06
72.0	.361E -1	-37.90	-145.48	.154E -8	-185.30	139.35
74.0	.938E -1	-29.61	-174.40	.185E -8	-183.71	56.27
76.0	.343E -1	-38.36	116.90	.212E -8	-182.52	-55.96
78.0	.525E -1	-34.65	127.94	.235E -8	-181.65	159.31
80.0	.761E -1	-31.42	-22.38	.248E -8	-181.17	-19.08
82.0	.544E -1	-34.34	151.27	.249E -8	-181.13	128.56
84.0	.256E -1	-40.89	-47.30	.242E -8	-181.39	-117.69
86.0	.246E -1	-41.23	110.64	.231E -8	-181.76	-37.28
88.0	.344E -1	-38.32	-172.61	.223E -8	-182.10	10.54
90.0	.375E -1	-37.58	-150.06	.217E -8	-182.31	26.41

CPU TIME = 22.02 SECONDS

Example 4 uses the circular reflector of example 1 except that near field results are calculated instead of far field patterns. In this example, two constant range cases with R=100λ and R=40λ, are shown in Figures 19 and 20, respectively, and the input data are given below. Note that only AI is used in this example. A good agreement between AI and GTD has been verified in Reference 5.

```
NF:
1,1
Ø.,Ø.,Ø.,Ø.
PZ:
1
1Ø7.3742
Ø.,9Ø.,2.
XQ:
PZ:
1
42.9497
Ø.,9Ø.,2.
XQ:
```

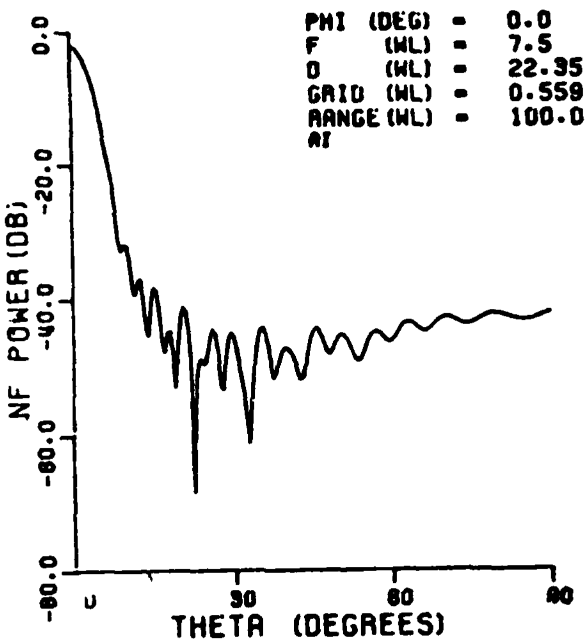


Figure 19. Principal near field component for 22.35λ diameter circular reflector. R=100λ.

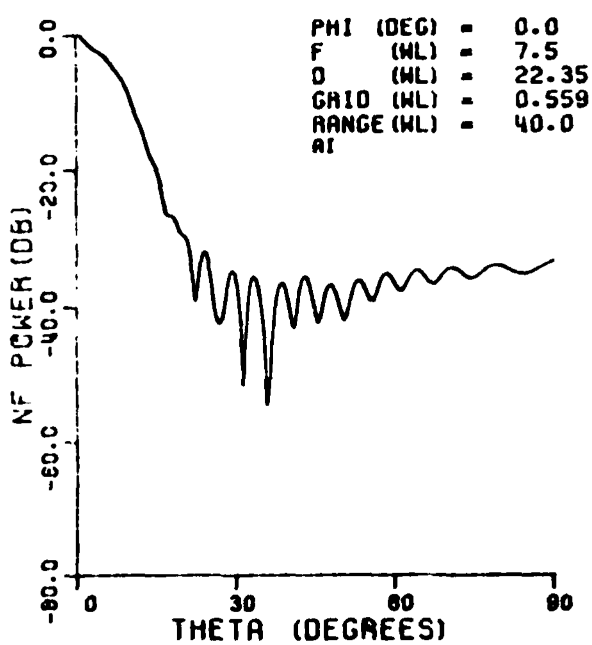


Figure 20. Principal near field component for 22.35λ diameter circular reflector. R=40λ.

The output data for Example 4 as calculated by AI for R=100λ are given below:

```
*****************************************************************************
*                                                                           *
*                 DEFAULT DATA                                              *
*                                                                           *
*                                                                           *
*  LINEAR DIMENSION INPUTS ARE IN INCHES                                    *
*                                                                           *
*     CIRCULAR REFLECTOR WITH APERTURE DIAMETER =     24.00                 *
*                                                                           *
*                                                                           *
*       FOCAL DISTANCE=      8.00 GRIDX=    .600      GRIDY =    .600       *
*                                                                           *
*     FEED PATTERN SYMMETRY GIVEN BY:ISYM= 1                                *
*                                                                           *
*     LINEARLY POLARIZED FEED                                               *
*                                                                           *
*       POLARIZED ANGLE =  90.00                                            *
*                                                                           *
*       FEED DATA INPUT IN DB.                                              *
*                                                                           *
*                                                                           *
*         NPW = 1                                                           *
*             N          PHIN(N)      PSIO(N)         AEX(N)       CAN(N)   *
*             1            0.0         120.0           5.0          .09     *
*             2           90.0         140.0           6.0          .10     *
*                                                                           *
*                                                                           *
*****************************************************************************


*****************************************************************************
*                                                                           *
*  PZ:                                                                      *
*                                                                           *
*                                                                           *
* USING THE PRESENT GEOMETRY,THERE WILL BE    1 PATTERN CUTS COMPUTED       *
*                                                                           *
*                                                                           *
* SINCE IP2 IS POSITIVE THE FOLLOWING CUTS WILL BE COMPUTED:                *
* 107.4,
*                                                                           *
*      AP3I =    0.00      AP3F =  90.00                                    *
*                                                                           *
*  FOR EACH CUT THE PATTERN WILL BE COMPUTED EACH   2.0 DEGREES THETA OR    *
*                                                                           *
*  INPUT UNIT IN RHO                                                        *
*                                                                           *
*                                                                           *
*                                                                           *
*****************************************************************************
```

XU:

PRAD = .134E 1

FREQUENCY = 11.000 GHZ

WAVELENGTH = .027273 METERS

* THE FOLLOWING DIMENSION UNITS ARE IN WAVELENGTHS *

NUMBER OF RIM SEGMENTS= 64

APERTURE DIAMETER = 22.35 WAVELENGTHS

APERTURE CENTER AT (0., 0.00)

COORDINATES OF RIM POINTS (WAVELENGTHS)

RIM POINT	X	Y
1	11.17	.55
2	11.06	1.64
3	10.85	2.72
4	10.53	3.77
5	10.11	4.78
6	9.59	5.75
7	8.98	6.66
8	8.29	7.51
9	7.51	8.29
10	6.66	8.98
11	5.75	9.59
12	4.78	10.11
13	3.77	10.53
14	2.72	10.85
15	1.64	11.06
16	.55	11.17
17	-.55	11.17
18	-1.64	11.06

19	-2.72	10.85
20	-3.77	10.53
21	-4.78	10.11
22	-5.75	9.59
23	-6.66	8.98
24	-7.51	8.29
25	-8.29	7.51
26	-8.98	6.66
27	-9.59	5.75
28	-10.11	4.78
29	-10.53	3.77
30	-10.85	2.72
31	-11.06	1.64
32	-11.17	.55
33	-11.17	-.55
34	-11.06	-1.64
35	-10.85	-2.72
36	-10.53	-3.77
37	-10.11	-4.78
38	-9.59	-5.75
39	-8.98	-6.66
40	-8.29	-7.51
41	-7.51	-8.29
42	-6.66	-8.98
43	-5.75	-9.59
44	-4.78	-10.11
45	-3.77	-10.53
46	-2.72	-10.85
47	-1.64	-11.06
48	-.55	-11.17
49	.55	-11.17
50	1.64	-11.06
51	2.72	-10.85
52	3.77	-10.53
53	4.78	-10.11
54	5.75	-9.59
55	6.66	-8.98
56	7.51	-8.29
57	8.29	-7.51
58	8.98	-6.66
59	9.59	-5.75
60	10.11	-4.78
61	10.53	-3.77
62	10.85	-2.72
63	11.06	-1.64
64	11.17	-.55

FOCAL DISTANCE = 7.45

GRIDX = .56 GRIDY = .56

REFDB = 0.000

PHI = 0.00

NEAR FIELD WITH CONSTANT RANGE R = 100.00

		PRINCIPAL POL			CROSS POL	
THETA	MAG	DB	PHASE	MAG	DB	PHASE
0.0	.802E 0	-1.92	-25.24	.159E -8	-175.99	-25.23
2.0	.658E 0	-3.64	-4.61	.289E -8	-170.77	-3.45
4.0	.405E 0	-7.85	40.52	.168E -8	-175.51	82.71
6.0	.145E 0	-16.79	110.81	.185E -8	-174.64	174.42
8.0	.448E -1	-26.97	-151.34	.158E -8	-176.02	-102.27
10.0	.251E -1	-32.01	3.07	.707E -9	-183.01	-34.27
12.0	.134E -1	-37.46	155.98	.144E -9	-196.82	76.10
14.0	.543E -2	-45.31	-47.85	.180E -9	-194.92	-88.53
16.0	.874E -2	-41.17	37.60	.457E-10	-206.80	21.89
18.0	.587E -2	-44.63	-165.14	.530E-10	-205.52	-171.73
20.0	.734E -2	-42.69	7.12	.420E-10	-207.54	-83.12
22.0	.285E -2	-50.92	40.15	.626E-10	-204.07	110.44
24.0	.358E -2	-48.93	-99.46	.123E-10	-218.20	-136.82
26.0	.596E -2	-44.49	7.48	.821E-11	-221.71	-125.25
28.0	.217E -2	-53.26	-73.06	.607E-10	-204.33	170.66
30.0	.526E -2	-45.59	-90.98	.257E-10	-211.79	-95.29
32.0	.198E -2	-54.09	-20.86	.122E-10	-218.28	79.33
34.0	.376E -2	-48.49	-124.20	.745E-10	-202.56	168.16
36.0	.553E -2	-45.15	-123.40	.475E-10	-206.47	-162.09
38.0	.289E -2	-50.80	162.36	.170E-10	-215.37	139.19
40.0	.434E -2	-47.26	159.08	.497E-10	-206.07	159.31
42.0	.296E -2	-50.56	173.68	.485E-10	-206.28	-170.68
44.0	.425E -2	-47.44	106.94	.325E-10	-209.78	174.00
46.0	.593E -2	-44.54	91.47	.460E-10	-206.74	149.42
48.0	.395E -2	-48.07	46.92	.389E-10	-208.20	140.57
50.0	.531E -2	-45.49	4.71	.279E-10	-211.09	109.93
52.0	.465E -2	-46.65	-5.11	.296E-10	-210.59	119.09
54.0	.357E -2	-48.95	-45.87	.367E-10	-208.70	171.14
56.0	.530E -2	-45.51	-79.39	.406E-10	-207.83	-169.90
58.0	.552E -2	-45.16	-99.48	.333E-10	-209.56	174.87
60.0	.465E -2	-46.29	-144.00	.422E-10	-207.49	153.65
62.0	.620E -2	-44.16	172.37	.530E-10	-205.51	155.90
64.0	.660E -2	-43.61	143.21	.499E-10	-206.04	172.71
66.0	.579E -2	-44.75	103.59	.412E-10	-207.71	-178.01
68.0	.627E -2	-44.05	56.28	.266E-10	-211.49	179.74
70.0	.720E -2	-42.85	20.99	.183E-10	-214.76	162.49
72.0	.702E -2	-43.08	-12.04	.203E-10	-213.84	136.31
74.0	.645E -2	-43.81	-53.20	.252E-10	-211.98	144.66
76.0	.674E -2	-43.43	-98.15	.312E-10	-210.13	156.11
78.0	.745E -2	-42.55	-137.33	.400E-10	-207.95	158.77
80.0	.770E -2	-42.27	-173.10	.451E-10	-206.92	155.13
82.0	.740E -2	-42.62	149.41	.454E-10	-206.86	147.44
84.0	.700E -2	-43.10	107.86	.401E-10	-207.94	137.16
86.0	.695E -2	-43.17	63.67	.319E-10	-209.92	128.14
88.0	.731E -2	-42.72	19.89	.217E-10	-213.29	125.98
90.0	.787E -2	-42.08	-22.27	.140E-10	-217.06	149.06

CPU TIME = 225.49 SECONDS

The output data for Example 4 as calculated by AI for R=40λ are given below:

```
*****************************************************************************
*                                                                           *
*  PZ:                                                                      *
*                                                                           *
*                                                                           *
* USING THE PRESENT GEOMETRY,THERE WILL BE    1 PATTERN CUTS COMPUTED       *
*                                                                           *
*                                                                           *
* SINCE IP2 IS POSITIVE THE FOLLOWING CUTS WILL BE COMPUTED:                *
*  42.9,
*                                                                           *
*     AP3I =    0.00      AP3F =   90.00                                    *
*                                                                           *
*  FOR EACH CUT THE PATTERN WILL BE COMPUTED EACH   2.0 DEGREES THETA OR    *
*                                                                           *
*  INPUT UNIT IN RHO                                                        *
*                                                                           *
*                                                                           *
*                                                                           *
*****************************************************************************


*****************************************************************************
*                                                                           *
*  XO:                                                                      *
*                                                                           *
*                                                                           *
*       PRAD =  .134E  1                                                    *
*                                                                           *
*       FREQUENCY =     11.000 GHZ                                          *
*                                                                           *
*       WAVELENGTH =      .027273 METERS                                    *
*       * THE FOLLOWING DIMENSION UNITS ARE IN WAVELENGTHS *                *
*                                                                           *
*       NUMBER OF RIM SEGMENTS= 64                                          *
*                                                                           *
*                                                                           *
*       APERTURE DIAMETER =    22.35 WAVELENGTHS                            *
*                                                                           *
*       APERTURE CENTER AT (0.,   0,00)                                     *
*                                                                           *
*       COORDINATES OF RIM POINTS (WAVELENGTHS)                             *
*                RIM POINT        X              Y                          *
*                    1          11.17           .55                         *
*                    2          11.06          1.64                         *
*                    3          10.85          2.72                         *
*                    4          10.53          3.77                         *
*                    5          10.11          4.78                         *
*                    6           9.59          5.75                         *
```

*	7	8.98	6.66	*
*	8	8.29	7.51	*
*	9	7.51	8.29	*
*	10	6.66	8.98	*
*	11	5.75	9.59	*
*	12	4.78	10.11	*
*	13	3.77	10.53	*
*	14	2.72	10.85	*
*	15	1.64	11.06	*
*	16	.55	11.17	*
*	17	-.55	11.17	*
*	18	-1.64	11.06	*
*	19	-2.72	10.85	*
*	20	-3.77	10.53	*
*	21	-4.78	10.11	*
*	22	-5.75	9.59	*
*	23	-6.66	8.98	*
*	24	-7.51	8.29	*
*	25	-8.29	7.51	*
*	26	-8.98	6.66	*
*	27	-9.59	5.75	*
*	28	-10.11	4.78	*
*	29	-10.53	3.77	*
*	30	-10.85	2.72	*
*	31	-11.06	1.64	*
*	32	-11.17	.55	*
*	33	-11.17	-.55	*
*	34	-11.06	-1.64	*
*	35	-10.85	-2.72	*
*	36	-10.53	-3.77	*
*	37	-10.11	-4.78	*
*	38	-9.59	-5.75	*
*	39	-8.98	-6.66	*
*	40	-8.29	-7.51	*
*	41	-7.51	-8.29	*
*	42	-6.66	-8.98	*
*	43	-5.75	-9.59	*
*	44	-4.78	-10.11	*
*	45	-3.77	-10.53	*
*	46	-2.72	-10.85	*
*	47	-1.64	-11.06	*
*	48	-.55	-11.17	*
*	49	.55	-11.17	*

50	1.64	-11.06
51	2.72	-10.85
52	3.77	-10.53
53	4.78	-10.11
54	5.75	-9.59
55	6.66	-8.98
56	7.51	-8.29
57	8.29	-7.51
58	8.98	-6.66
59	9.59	-5.75
60	10.11	-4.78
61	10.53	-3.77
62	10.85	-2.72
63	11.06	-1.64
64	11.17	-.55

FOCAL DISTANCE = 7.45

GRIDX = .56 GRIDY = .56

REFDB = 0.000

PHI = 0.00

NEAR FIELD WITH CONSTANT RANGE R = 40.00

	PRINCIPAL POL			CROSS POL		
THETA	MAG	DB	PHASE	MAG	DB	PHASE
0.0	.103E 1	.26	-36.81	.193E -8	-174.27	-35.97
2.0	.897E 0	-.94	-27.12	.244E -8	-172.26	-17.85
4.0	.763E 0	-2.35	-3.03	.159E -8	-175.95	-18.03
6.0	.651E 0	-3.73	31.77	.227E -8	-172.87	35.73
8.0	.510E 0	-5.86	91.11	.331E -8	-169.60	99.55
10.0	.348E 0	-9.16	164.56	.388E -8	-168.23	179.74
12.0	.219E 0	-13.18	-100.38	.328E -8	-169.69	-103.31
14.0	.125E 0	-18.03	6.19	.214E -8	-173.39	-13.27
16.0	.778E -1	-22.18	114.77	.101E -8	-179.93	98.71
18.0	.466E -1	-26.63	-103.22	.603E -9	-184.39	-150.50
20.0	.338E -1	-29.42	22.23	.321E -9	-189.86	8.57
22.0	.171E -1	-35.36	134.88	.298E -9	-190.53	141.84
24.0	.255E -1	-31.86	-54.41	.121E -9	-198.37	-114.17
26.0	.110E -1	-39.20	41.91	.158E -9	-196.01	84.98
28.0	.102E -1	-39.79	-125.17	.249E -9	-192.06	-173.32
30.0	.179E -1	-34.95	-43.20	.346E-10	-209.21	-109.86
32.0	.636E -2	-43.93	-153.07	.261E -9	-191.68	131.16
34.0	.161E -1	-35.87	-128.50	.138E -9	-197.22	-164.54
36.0	.191E -2	-54.38	-105.34	.595E-10	-204.51	104.77

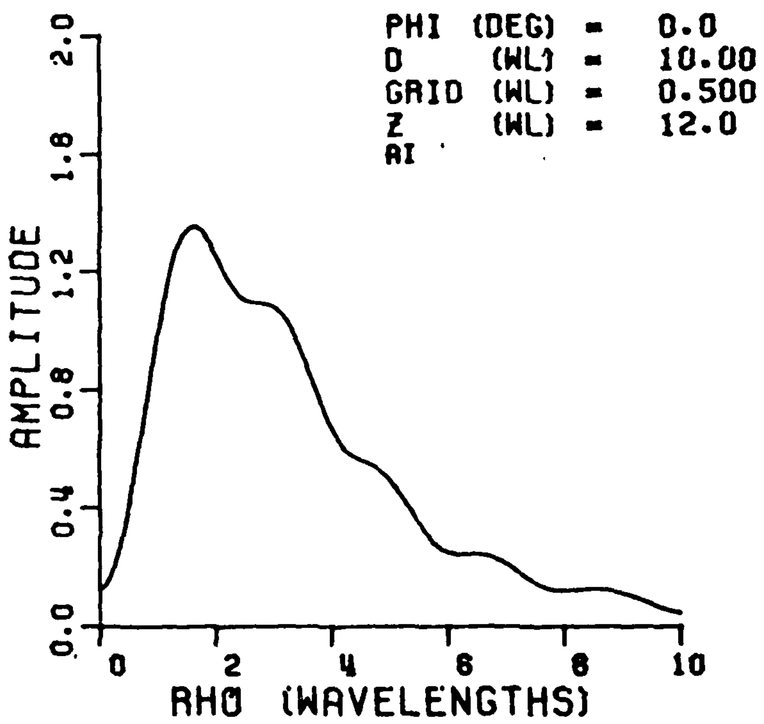
W	38.0	.130E -1	-37.70	173.86	.251E -9	-192.01	149.16	W
W	40.0	.111E -1	-39.10	-168.03	.206E -9	-193.72	-172.32	W
W	42.0	.127E -1	-37.94	107.23	.974E-10	-200.23	114.62	W
W	44.0	.149E -1	-36.51	107.24	.205E -9	-193.78	141.09	W
W	46.0	.832E -2	-41.60	45.52	.124E -9	-198.13	164.88	W
W	48.0	.146E -1	-36.72	29.48	.853E-10	-201.38	110.32	W
W	50.0	.907E -2	-40.85	19.30	.132E -9	-197.56	126.76	W
W	52.0	.124E -1	-38.11	-40.87	.147E -9	-196.68	142.74	W
W	54.0	.151E -1	-36.41	-50.17	.163E -9	-195.74	143.34	W
W	56.0	.111E -1	-39.12	-95.58	.211E -9	-193.51	153.22	W
W	58.0	.167E -1	-35.52	-137.74	.190E -9	-194.45	166.26	W
W	60.0	.156E -1	-36.16	-160.11	.137E -9	-197.27	-172.31	W
W	62.0	.137E -1	-37.27	146.56	.763E-10	-202.35	158.47	W
W	64.0	.182E -1	-34.81	109.95	.965E-10	-200.31	134.04	W
W	66.0	.167E -1	-35.54	81.99	.110E -9	-199.18	134.24	W
W	68.0	.150E -1	-36.50	33.15	.647E-10	-203.78	147.24	W
W	70.0	.184E -1	-34.68	-8.33	.204E-10	-213.81	166.88	W
W	72.0	.190E -1	-34.43	-38.37	.301E-10	-210.43	123.87	W
W	74.0	.165E -1	-35.65	-77.51	.726E-10	-202.78	122.68	W
W	76.0	.169E -1	-35.45	-126.03	.123E -9	-198.18	142.63	W
W	78.0	.194E -1	-34.22	-165.76	.169E -9	-195.46	142.00	W
W	80.0	.201E -1	-33.94	160.05	.188E -9	-194.52	140.65	W
W	82.0	.186E -1	-34.60	122.79	.184E -9	-194.72	139.21	W
W	84.0	.174E -1	-35.19	79.03	.162E -9	-195.81	133.78	W
W	86.0	.179E -1	-34.93	32.78	.146E -9	-196.69	134.54	W
W	88.0	.197E -1	-34.12	-10.75	.115E -9	-198.79	140.70	W
W	90.0	.216E -1	-33.29	-51.40	.120E -9	-198.44	161.47	W

CPU TIME = 450.75 SECONDS **(for both patterns of Example 4)**

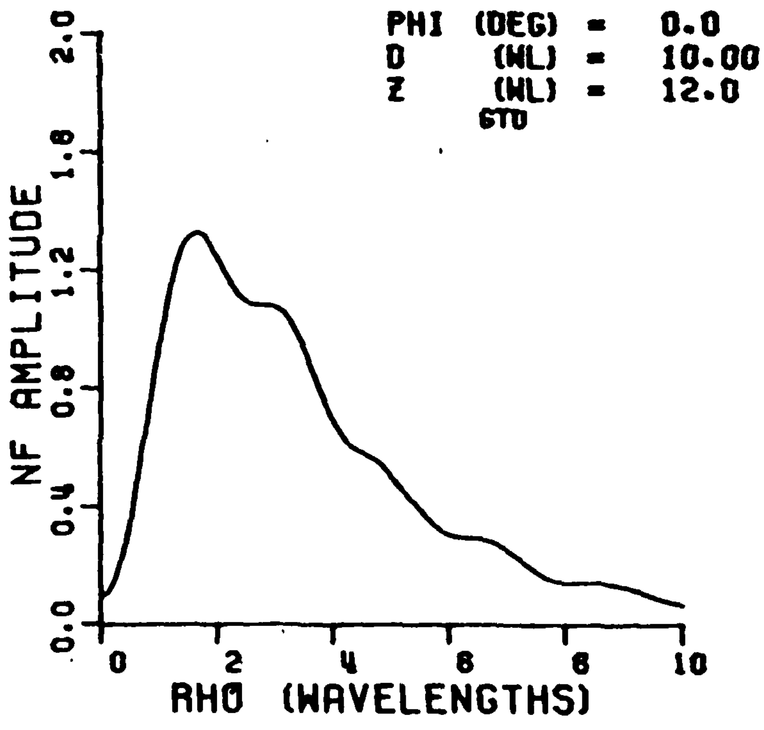
*   *
*   *
****

Example 5 illustrates near field calculations with a constant z-cut. The reflector is a circular one with diameter D=10λ and an isotropic feed located at a focal distance F=10,000λ. The y component of the near field results as computed by AI and GTD for the constant plane cut at z=12λ are shown in Figures 21 a and b, respectively. The input data are given below:

```
DG:
2,100ØØ.,Ø.5,Ø.5,1Ø.
TO:
F,F,F,F,F
T,T
F,F,T
Ø.,Ø.
FD:
F,F,F,1,9Ø.
2,Ø.,9Ø.
Ø.,Ø.,Ø.,18Ø.,Ø.,Ø.,18Ø.
FQ:
1,11.81102362
NF:
T,F
Ø.,Ø.,Ø.,Ø.
FZ:
1
1Ø.
Ø.,12.,Ø.2
XQ:
```



(a) Aperture Integration (AI)



(b) GTD

Figure 21. Near field component E_y for 10λ diameter circular reflector. $Z=12\lambda$.

The output data for example 5 as calculated by GTD are given below:

```
****************************************************************************
*                                                                          *
*                   DEFAULT DATA                                           *
*                                                                          *
*                                                                          *
*  LINEAR DIMENSION INPUTS ARE IN INCHES                                   *
*                                                                          *
*    CIRCULAR REFLECTOR WITH APERTURE DIAMETER =     24.00                 *
*                                                                          *
*                                                                          *
*      FOCAL DISTANCE=      8.00 GRIDX=    .600      GRIDY =    .600       *
*                                                                          *
*    FEED PATTERN SYMMETRY GIVEN BY:ISYM= 1                                *
*                                                                          *
*    LINEARLY POLARIZED FEED                                               *
*                                                                          *
*      POLARIZED ANGLE =  90.00                                            *
*                                                                          *
*      FEED DATA INPUT IN DB.                                              *
*                                                                          *
*                                                                          *
*        NPW = 1                                                           *
*            N            PHIN(N)      PSIO(N)        AEX(N)      CAN(N)   *
*            1              0.0         120.0          5.0         .09     *
*            2             90.0         140.0          6.0         10      *
*                                                                          *
*                                                                          *
****************************************************************************


****************************************************************************
*                                                                          *
*  DG:                                                                     *
*                                                                          *
*                                                                          *
*  LINEAR DIMENSION INPUTS ARE IN INCHES                                   *
*                                                                          *
*    CIRCULAR REFLECTOR WITH APERTURE DIAMETER =     10.00                 *
*                                                                          *
*                                                                          *
*      FOCAL DISTANCE= 10000.00 GRIDX=    .500      GRIDY =    .500        *
*                                                                          *
*                                                                          *
****************************************************************************
```

```
FO:

   LDEBUG=  F      LTEST=  F      LWYSUM= F      LOUT = F      LWFD = F

   LSLOPE=  T      LCORNR=  T

   LAI = F         LFEED = F       LGTD = T

   THETAX = 0.00      ZX =      0.000
```

```
FD:

   FEED PATTERN SYMMETRY GIVEN BY:ISYM= 1

   LINEARLY POLARIZED FEED

     POLARIZED ANGLE =  90.00

     LINEAR FEED DATA INPUT

       NPW = 0
           N          PHIN(N)        PSIO(N)          AEX(N)        CAN(N)
           1            0.0           180.0             0.0          0.00
           2           90.0           180.0             0.0          0.00
```

```
FQ:

FOR THIS GEOMETRY,THERE WILL BE   1 FREQUENCIES CONSIDERED AS FOLLOWS:
11.81,
```

```
**********************************************************************
*                                                                    *
*  NF:                                                               *
*                                                                    *
*                                                                    *
*                                                                    *
   NEAR FIELD PATTERN WILL BE CALCULATED                             *
*       IN PHIE =    0.00 DEGREE CUT, AND ORIGIN AT (   0.00,   0.00,   0.00, )  *
*       WITH CONTANT Z CUT                                           *
*                                                                    *
*                                                                    *
**********************************************************************


**********************************************************************
*                                                                    *
*  P2:                                                               *
*                                                                    *
*                                                                    *
*  USING THE PRESENT GEOMETRY,THERE WILL BE    1 PATTERN CUTS COMPUTED  *
*                                                                    *
*                                                                    *
*  SINCE IP2 IS POSITIVE THE FOLLOWING CUTS WILL BE COMPUTED:        *
*  12.0,                                                             *
*                                                                    *
*     AP3I =    0.00      AP3F =  10.00                              *
*                                                                    *
*  FOR EACH CUT THE PATTERN WILL BE COMPUTED EACH     .2 DEGREES THETA OR  *
*                                                                    *
*  INPUT UNIT IN RHO                                                 *
*                                                                    *
*                                                                    *
*                                                                    *
**********************************************************************
```

```
XQ:

      PRAD =  .126E  2

      FREQUENCY =    11.811 GHZ

      WAVELENGTH =      .025400 METERS
       * THE FOLLOWING DIMENSION UNITS ARE IN WAVELENGTHS *

      NUMBER OF RIM SEGMENTS= 16


      APERTURE DIAMETER =    10.00 WAVELENGTHS

      APERTURE CENTER AT (0.,    0.00)

      COORDINATES OF RIM POINTS (WAVELENGTHS)
                  RIM POINT          X              Y
                      1            4.95            .99
                      2            4.20           2.81
                      3            2.81           4.20
                      4             .99           4.95
                      5            -.99           4.95
                      6           -2.81           4.20
                      7           -4.20           2.81
                      8           -4.95            .99
                      9           -4.95           -.99
                     10           -4.20          -2.81
                     11           -2.81          -4.20
                     12            -.99          -4.95
                     13             .99          -4.95
                     14            2.81          -4.20
                     15            4.20          -2.81
                     16            4.95           -.99

        FOCAL DISTANCE = 10000.00

        GRIDX =    .50      GRIDY =    .50


        REFDB =   -80.000


PHI =      0.00

      NEAR FIELD OBSERVATION PLANE AT Z =      12.00
```

W	RHO	EX MAG	EX DB	EX PHASE	EY MAG	EY DB	EY PHASE	EZ MAG	EZ DB	EZ PHASE

THE REFLECTED SHADOW BOUNDARIES IN THE PHIE PLANE ARE AT

RHOS1 = 4.952 AND RHOS2 = -4.952

W	0.00	.468E-11	-226.59	6.37	.981E -1	-20.16	127.59	.327E -7	-149.71	-175.92
W	.20	.187E -8	-174.58	-85.90	.133E 0	-17.55	146.03	.252E -7	-151.97	-176.61
W	.40	.353E -8	-169.05	-87.50	.261E 0	-11.68	165.22	.230E -7	-152.76	-179.04
W	.60	.481E -8	-166.36	-90.35	.466E 0	-6.64	172.52	.197E -7	-154.11	176.49
W	.80	.585E -8	-164.66	-93.98	.706E 0	-3.02	174.70	.155E -7	-156.17	171.14
W	1.00	.585E -8	-164.66	-99.17	.944E 0	-.50	174.89	.112E -7	-159.03	158.15
W	1.20	.682E -8	-163.33	-109.71	.114E 1	1.15	174.31	.721E -8	-162.85	165.46
W	1.40	.498E -8	-166.06	-123.92	.127E 1	2.09	173.66	.342E -8	-169.31	100.57
W	1.60	.449E -8	-166.95	-158.36	.133E 1	2.46	173.44	.993E -8	-160.06	133.38
W	1.80	.237E -8	-172.49	-149.07	.131E 1	2.37	174.26	.236E -8	-172.54	-19.43
W	2.00	.129E -8	-177.81	-170.64	.125E 1	1.95	176.69	.318E -8	-169.95	-52.87
W	2.20	.370E -9	-188.64	130.97	.117E 1	1.39	-178.89	.344E -8	-169.27	-76.67
W	2.40	.143E -8	-176.89	47.61	.111E 1	.94	-173.03	.390E -8	-168.19	-62.51
W	2.60	.185E -8	-174.64	-12.64	.109E 1	.73	-167.17	.151E -8	-176.43	-126.49
W	2.80	.148E -8	-176.60	-13.02	.108E 1	.70	-162.94	.261E -8	-171.66	-133.31
W	3.00	.181E -8	-174.84	-26.71	.108E 1	.65	-161.06	.192E -8	-174.32	-173.36
W	3.20	.139E -8	-177.12	-73.35	.105E 1	.40	-161.16	.168E -8	-175.51	68.49
W	3.40	.113E -8	-178.93	-92.19	.982E 0	-.16	-162.54	.190E -8	-174.44	45.12
W	3.60	.431E -9	-187.31	-111.50	.889E 0	-1.02	-164.10	.157E -8	-176.10	6.47
W	3.80	.126E -9	-198.01	172.65	.786E 0	-2.09	-165.00	.143E -8	-176.90	-26.76
W	4.00	.347E -9	-189.20	54.71	.694E 0	-3.17	-164.70	.133E -8	-177.51	-61.27
W	4.20	.221E -8	-173.10	11.25	.630E 0	-4.02	-163.66	.593E -8	-164.54	-165.55
W	4.40	.128E -8	-177.85	41.64	.595E 0	-4.51	-163.38	.754E -9	-182.45	-153.61
W	4.60	.107E -8	-179.44	24.40	.575E 0	-4.80	-165.36	.888E -9	-181.03	150.50
W	4.80	.584E -9	-184.67	-39.85	.551E 0	-5.18	-169.94	.695E -9	-183.16	111.88
W	5.00	.537E -9	-185.39	-51.08	.531E 0	-5.50	-173.13	.756E -9	-182.43	79.39
W	5.20	.332E -9	-189.58	-88.77	.456E 0	-6.82	175.27	.846E -9	-181.45	55.42
W	5.40	.707E -9	-183.01	139.62	.413E 0	-7.67	167.46	.591E -9	-184.57	-102.04
W	5.60	.494E -9	-186.12	46.50	.369E 0	-8.66	161.17	.111E -8	-179.13	-90.91
W	5.80	.574E -9	-184.82	-2.27	.330E 0	-9.64	156.55	.375E -9	-188.52	157.37
W	6.00	.241E -8	-172.35	11.78	.306E 0	-10.29	152.42	.497E -8	-166.07	-162.16
W	6.20	.136E -8	-177.35	-41.32	.297E 0	-10.55	146.48	.246E -8	-172.18	69.74
W	6.40	.280E -8	-171.06	-72.52	.295E 0	-10.62	137.11	.142E -8	-176.96	94.53
W	6.60	.107E -8	-179.42	-105.43	.289E 0	-10.78	124.28	.140E -8	-177.09	53.14
W	6.80	.851E -9	-181.41	-145.89	.276E 0	-11.19	108.96	.163E -8	-175.75	22.09
W	7.00	.100E -8	-179.99	-162.51	.253E 0	-11.92	92.22	.159E -8	-175.99	-8.48
W	7.20	.787E -9	-182.08	163.58	.226E 0	-12.93	75.21	.154E -8	-176.26	-47.33
W	7.40	.109E -8	-179.24	60.38	.197E 0	-14.10	59.00	.898E -9	-180.93	-88.77
W	7.60	.657E -9	-183.65	83.12	.170E 0	-15.40	43.71	.875E -9	-181.16	-119.11
W	7.80	.431E-10	-207.30	-56.03	.150E 0	-16.46	29.41	.113E -8	-178.93	122.79
W	8.00	.233E -8	-172.64	82.30	.143E 0	-16.86	14.93	.517E -8	-165.72	-96.30
W	8.20	.110E -8	-179.18	-69.47	.143E 0	-16.92	-2.24	.410E -9	-187.75	52.55
W	8.40	.103E -8	-179.73	171.37	.143E 0	-16.87	-22.99	.281E -8	-171.02	9.73
W	8.60	.238E -9	-192.48	-136.69	.142E 0	-16.94	-46.64	.721E -9	-182.84	31.93
W	8.80	.222E -9	-193.08	-164.16	.137E 0	-17.25	-72.68	.428E -9	-187.38	21.45
W	9.00	.105E -9	-199.59	-75.45	.128E 0	-17.84	-100.15	.362E -9	-188.82	-43.77
W	9.20	.348E -9	-189.16	-5.51	.118E 0	-18.59	-127.63	.146E -8	-176.72	-151.39
W	9.40	.411E -9	-187.73	89.74	.103E 0	-19.76	-155.38	.391E -9	-188.16	-95.76
W	9.60	.178E -9	-194.98	6.40	.878E -1	-21.13	178.31	.410E -9	-187.74	-135.12
W	9.80	.461E -9	-186.72	40.57	.750E -1	-22.50	154.41	.389E -9	-188.21	131.80
W	10.00	.517E -9	-185.73	9.15	.676E -1	-23.40	129.99	.627E -9	-184.05	110.83

CPU TIME = 39.69 SECONDS

REFERENCES

1. S. H. Lee and R. C. Rudduck, "Numerical Electromagnetic Code (NEC) - Reflector Antenna Code. Part II: Code Manual," Report 784508-16, September 1979, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Contract N00123-76-C-1371 for Naval Regional Procurement Office, Long Beach, California.

2. A. C. Ludwig, "The Definition of Cross Polarization," IEEE Trans. on Antennas and Propagation, AP-21, pp. 116-119, January 1973.

3. P. A. J. Ratnasiri, R. G. Kouyoumjian and P. H. Pathak, "The Wide Angle Side Lobes of Reflector Antennas," Report 2183-1, March 1970, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Contract AF 19(628)-5929 for Air Force Cambridge Research Laboratory.

4. H. P. Coleman, R. M. Brown, and G. D. Wright, "Paraboloidal Reflector Offset Fed with a Corrugated Conical Horn," IEEE Transactions on Antennas and Propagation, Vol. 23, November 1975, pp. 817-819.

5. R. C. Rudduck, R. J. Marhefka, W. D. Burnside, C. H. Walter, "Asymptotic High Frequency Techniques for UHF and Above Antennas," Report 784508-15, May 1979, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Contract N00123-76-C-1371 for Naval Regional Procurement Office, Long Beach, California 90822.

APPENDIX I
ANALYTIC FUNCTIONS FOR FEED PATTERNS

The reflector antenna code uses either a piecewise linear feed pattern, or the analytic functions described below. For sum patterns the analytic function is given by

$$F_{\Sigma}(\psi) = \frac{e^{-A\left(\frac{\psi}{\psi_o}\right)^2} \cos^N\left(\frac{\pi\psi}{2\psi_o}\right) + C}{1 + C} \qquad \text{(A-1)}$$

where the constants A, ψ_o and C can be controlled for each input pattern cut ϕ_o. The pattern value in Equation (A-1) is normalized such that $f_{\Sigma}(0) \equiv 1$ for all ϕ-plane cuts. The constants A, C and N control the shape of the pattern. The constant ψ_o permits a given pattern shape to be stretched or compressed.

For large values of $\frac{\psi}{\psi_o}$, $f_{\Sigma}(\psi) \rightarrow \frac{C}{1+C}$. In many cases this represents a spillover level that is too high for typical feed patterns. Consequently, the feed subroutine uses a linear taper under certain conditions for $\psi_L < \psi < 2\psi_L$, as shown in Figure 22, where

$$\psi_L = \sqrt{\frac{3}{A}} \; \psi_o \, . \qquad \text{(A-2)}$$

The linear taper was found to give reasonable results for the values of ψ_L in Equation (A-2), under the conditions that N=1, C>0, and A>3. Otherwise Equation (A-1) is used for the entire feed pattern cut, i.e., $\psi_L = 180^o$.

For difference feed patterns the analytic function is given by

$$f_{\Delta}(\psi) = C \, e^{-A\left(\frac{\psi}{\psi_o}\right)^2} \sin^N\left(\frac{\pi\psi}{2\psi_o}\right) \qquad \text{(A-3)}$$

for the entire feed pattern cut.

The parameters in Equations (A-1) and (A-3) correspond to the following input variables used in the code. Refer to the FD: Command.

Parameter	Code Name
N	NPW
A	AEX
C	CAN
ψ_o	PSIO

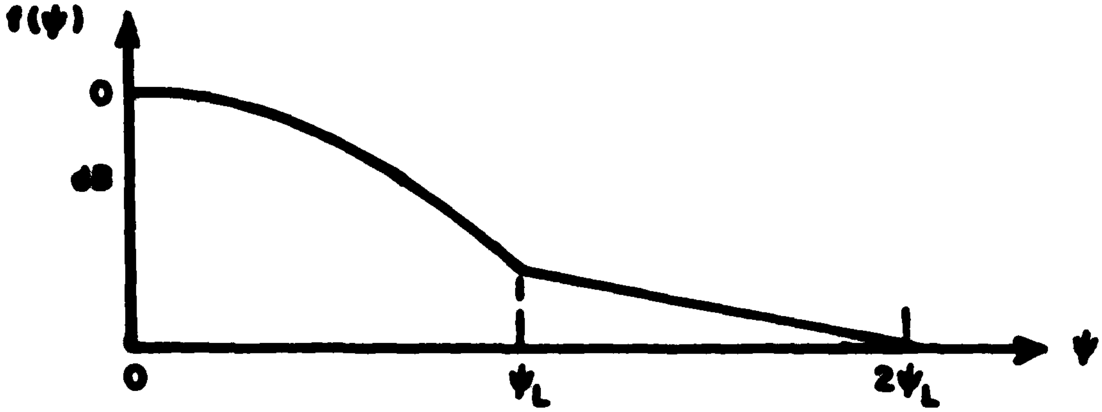


Figure 22. Analytic feed pattern with linear taper region.

F

5